EXAMPLES OF START-UP, COMMISSIONING, TROUBLESHOOTING AND MONITORING DOCUMENTATION: ENGINEERED LIQUID LOOP SOLAR HEATING SYSTEMS

Revised JANUARY 1984

Information, additional copies

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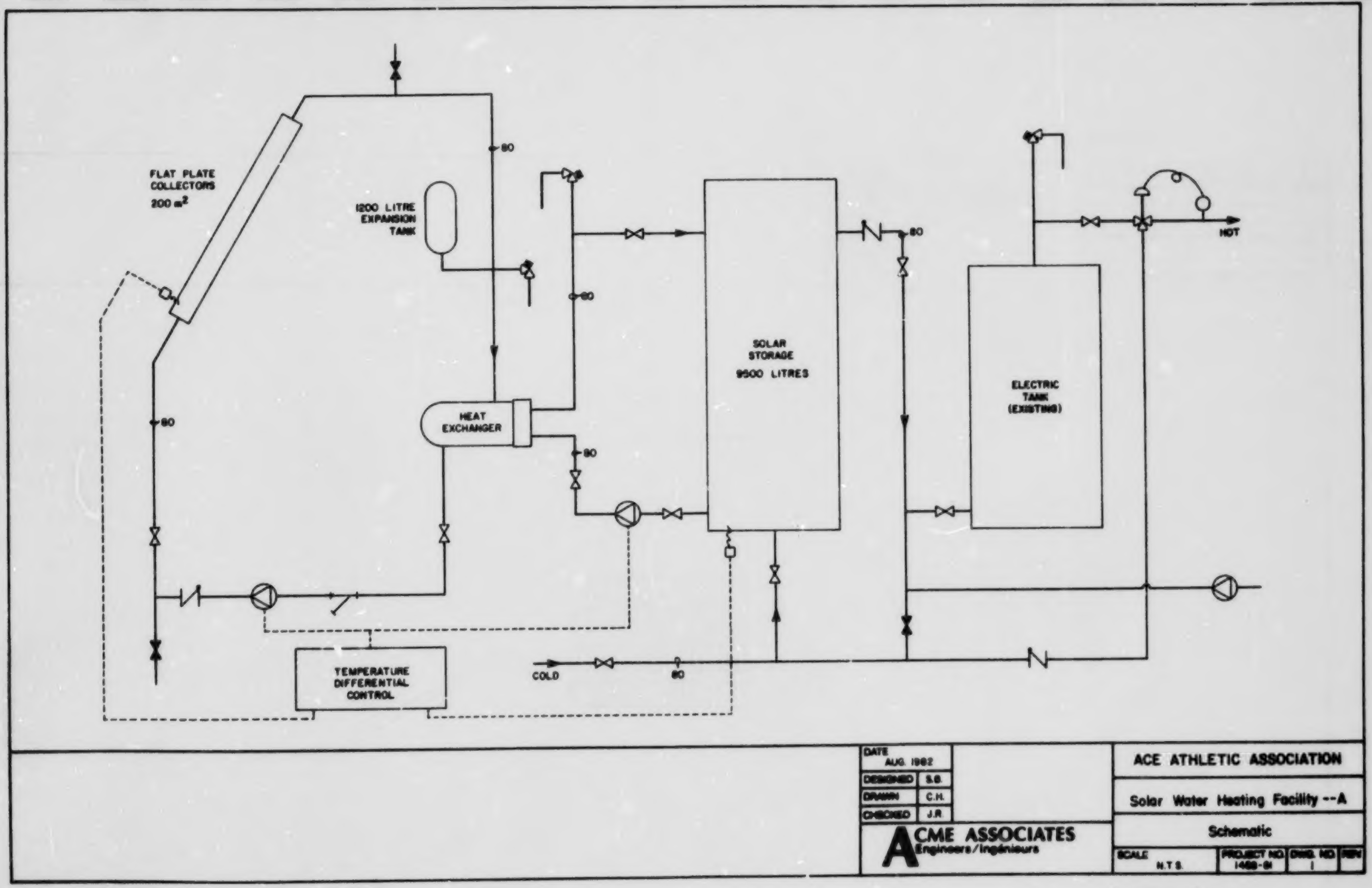
EXAMPLE SYSTEM "A"

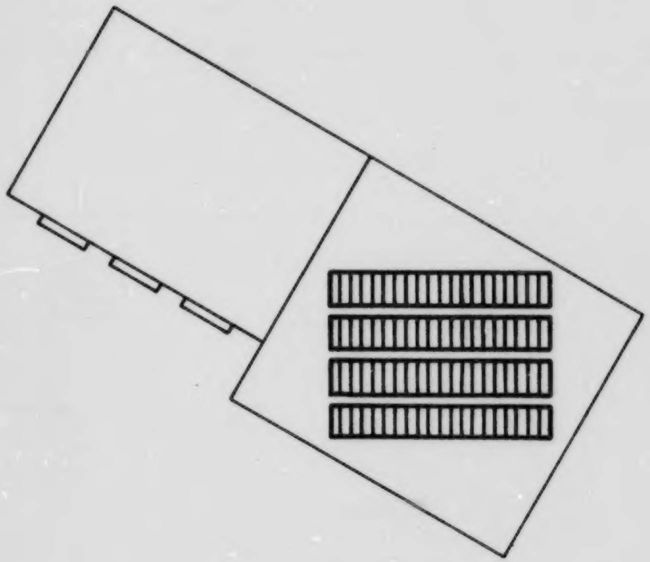
ACE ATHLETIC ASSOCIATION
CAFETERIA AND RECREATION COMPLEX
Solar Domestic Hot Water Heating System

This system is a basic domestic hot water or process hot water heating system with a closed loop glycol collection loop.

The auxiliary heating system consists of an electrically heated tank.


FLAT PLATE COLLECTORS 200 m²
1200 LITRE EXPANSION TANK
HEAT EXCHANGER
SOLAR STORAGE 9500 LITRES
ELECTRIC TANK (EXISTING)
TEMPERATURE DIFFERENTIAL CONTROL
80
80
80
80
80
80
COLD
HOT
DATE AUG. 1982
DESIGNED S.G.
DRAWN C.H.
CHECKED J.R.
ACME ASSOCIATES
Engineers/Ingénieurs
ACE ATHLETIC ASSOCIATION
Solar Water Heating Facility --A
Schematic
SCALE N.T.S.
PROJECT NO. 1468-81
DWG. NO. 1
REV

"SYSTEM A"



NOTE: COLLECTOR AREA = 200 m^2

DATE
AUG 1982
DESIGNED S.B.
DRAWN J.R.
CHECKED C.H.

ACME ASSOCIATES
Engineers/Ingénieurs

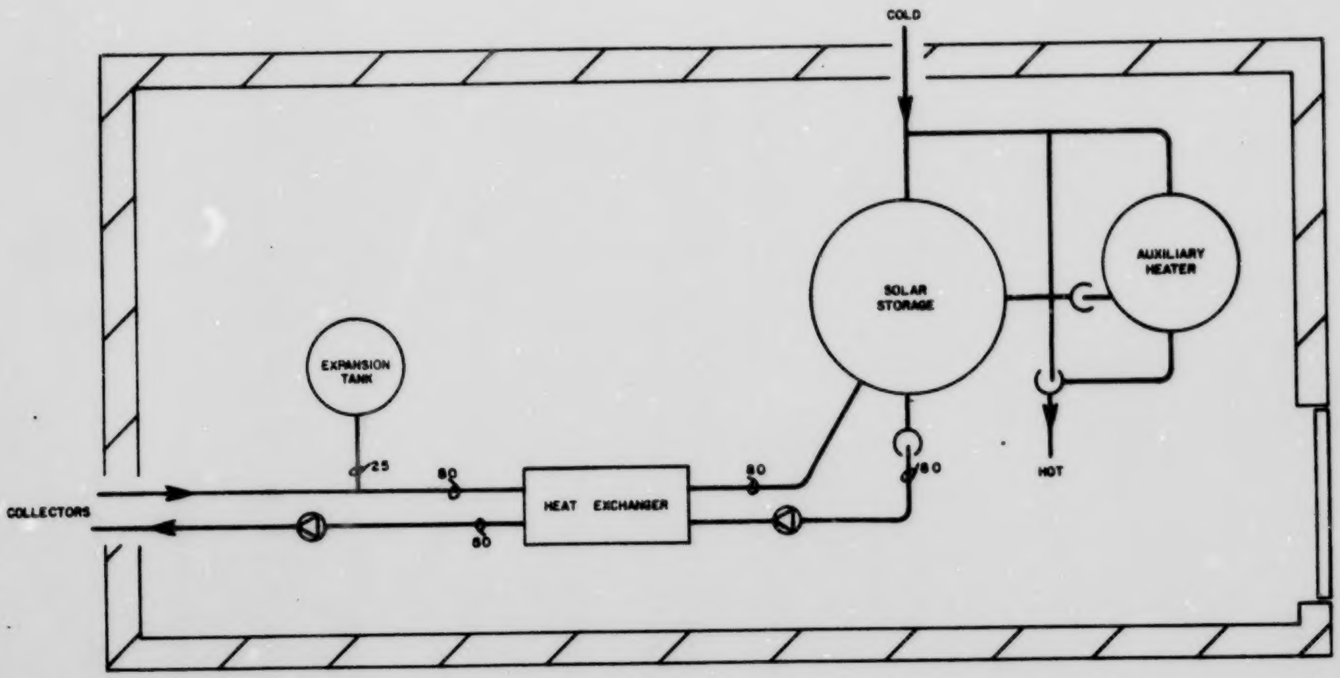
ACE ATHLETIC ASSOCIATION

Solar Water Heating Facility --A

COLLECTOR LAYOUT

SCALE	PROJECT NO.	DWG. NO.	REV
N.T.S.	1489-81	2	

"SYSTEM A"



DATE AUG. 1982		ACE ATHLETIC ASSOCIATION	
DESIGNED	S.B.	Solar Water Heating Facility --A	
DRAWN	J.R.	DOMESTIC HOT WATER EQUIPMENT ROOM	
CHECKED	C.H.		

ACME ASSOCIATES
Engineers/Ingénieurs

SCALE	PROJECT NO.	DWG. NO.	REV
N.T.S.	1488-81	3	

"SYSTEM A"

SELECTED INSTRUMENTATION

ACE ATHLETIC ASSOCIATION
CLOSED LOOP SYSTEM - DOMESTIC HOT WATER
CAFETERIA AND RECREATION CENTRE

1. Eleven Peterson Plugs, part number 110 to be installed at the specified locations in elbows.

2. Four Platinum RTD (DIN 43760), Omega Part No. 44031, wire-wound probes with accuracy of:

   plus or minus .3°C @ 0°C
   and plus or minus .6°C @ 100°C

3. Digital temperature readout; Omega Model 412A; 5 point selector switch, 4 wire lead-resistance compensated for Standard Platinum RTD (DIN 43760) with:

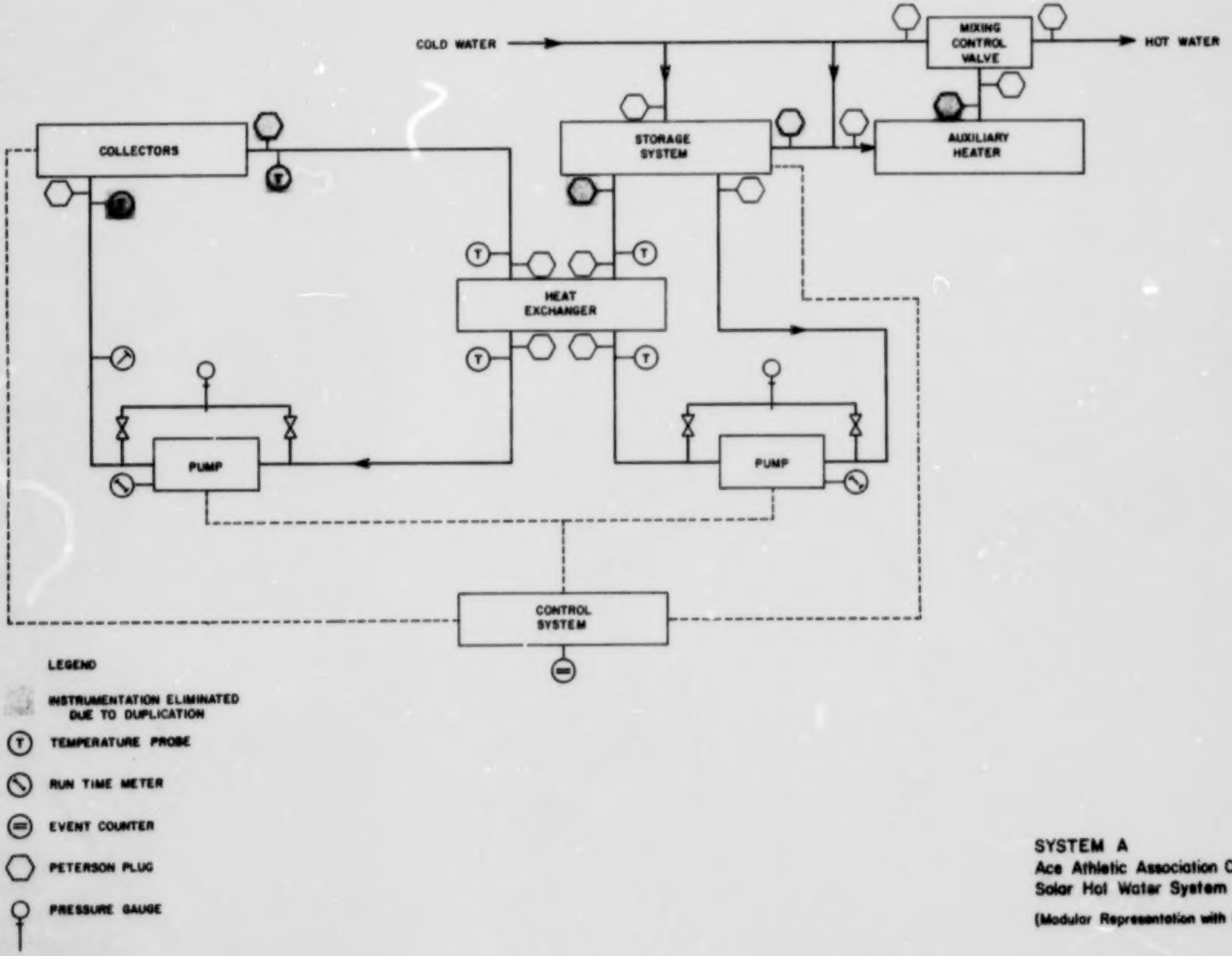
   range from 0°C - 100°C
   resolution of .1°C
   accuracy .1% of scale; plus or minus one digit
   sampling time - 1 second

4. Two Trerice pressure gauges with a range from 0 to 600 kPa.

5. Two Bach Simpson Number 1357 ETIF run time meters.

6. One Hecon AO - 040 event counter.

7. One Rada flow indicator; 700 kPa pressure rating, 100°C temperature rating.



SYSTEM A
Ace Athletic Association Closed Loop
Solar Hot Water System

(Modular Representation with Instrumentation)

START-UP PROCEDURES

ACE ATHLETIC ASSOCIATION
CLOSED LOOP SYSTEM - DOMESTIC HOT WATER
CAFETERIA AND RECREATION CENTRE

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1. General Introduction to Start-Up Document

Start-up is a series of tests and inspections performed during and immediately after construction to ensure that the system and its components are installed correctly, and are capable of operating at specified levels.

The following tests are performed during and immediately following the construction phase of the project. Since component testing does not require the system to be in a completed and operational mode, the component tests may be done immediately following the installation of the component. In cases where various pre-conditions must be met in order to perform the test, testing should be done at the earliest possible date following the installation of these components. When the system has been fully constructed, a final visual inspection and system flow checks should be performed.

Supportive documentation must be prepared following each test or series of tests. This documentation will be maintained in a project file and summarized when the testing is complete. This documentation will help the owner in his final assessment of the system.

Testing may be done whenever components are made available for testing. It is not necessary to test them in the order the tests are described.

2. Site Inspection

Preparations

- obtain a copy of the design specifications, design drawings and shop drawings;
- obtain copies of the manufacturer's specifications for all major components in the system (collectors, pumps, heat exchangers, controllers, control valves);
- prepare an "inspection" checklist. This should be a specification sheet that details the components that should be installed. This sheet will be updated and dated following each inspection;
- the contractor should attach a sticker to pump timers indicating:
    - the date the system became fully operational,
    - the pump timer reading on that date.

Collectors

- verify that the number and type of collectors specified in the shop drawings have been installed;
- verify that the collectors have been installed in accordance with the designer's and manufacturer's recommendations;
- verify that the collectors are fed from the bottom and returned from the top;
- check the security of all fasteners including those holding the collectors to the support structure, and those used in assembly of the support structure;
- ensure that load spreading washers have been used where necessary on collector attachment points;

- verify that flashings are firmly supported;
- ensure that there is a isolating gasket between any aluminum collectors and a steel frame.

Piping

- verify that all pipes, valves and fittings have been installed as specified;
- ensure that gate valves are used only for fully open or fully closed applications;
- verify that the pump is physically connected in the proper flow direction;
- verify that pumps have an adequate suction head.
- verify that the heat exchanger connections are made in the proper direction;
- verify that the expansion tank is on the suction side of the pump;
- verify that the pressure rating of the relief valve on the glycol loop is higher than the system pressure, but not higher than the rated pressure of the expansion tank;
- ensure that the collectors cannot be isolated from the expansion tank or pressure relief devices by closing valves;
- ensure that drain valves are located such that all piping can be drained;
- verify that there are sufficient pipe hangers, supports and expansion devices to compensate for thermal effects.

Insulation

- verify that the levels of insulation are as specified;
- verify that all insulation is:
    - securely fastened,
    - appropriately weatherproofed and protected from physical abuse,
    - protected from ultra-violet degradation (if applicable).
- verify that all test points are properly insulated;
- verify that any seams on piping jackets point downward to prevent moisture penetration;
- verify that there is insulation on the underside of storage tanks;
- verify that insulation does not impede the proper cooling of motors.

Thermal Storage

- verify that the storage tank is as specified or designed;
- verify that the pressure relief valves are installed and set to protect the system component with the lowest pressure rating;
- if a non-toxic fluid is specified, verify that a label is affixed in the vicinity of the fill valve, indicating that only non-toxic fluid be used.

Electrical

- verify that temperature sensors are firmly supported and protected from physical damage;
- ensure that all sensor wiring is protected from physical damage;
- verify that controls are located such that accidental adjustment is not possible;
- verify that wiring is installed according to local electrical codes;
- ensure that the instrumentation required for commissioning is available and properly installed.

3. Verification of Glycol Properties

Preparations

- the working fluid is tested to ensure that the mixture in the system will provide the required freeze protection, and that the fluid is of the proper type;

- it is important that ethylene glycol not be used in systems where contamination of potable water is possible;

- prepare a tabulation of the specified glycol properties:

  - type of antifreeze proplyene glycol
  - concentration - 50 % antifreeze
    (by volume) - 50 % water
  - acidity - pH 7.9
  - reserve alkalinity, minimum 10

- the solution should have circulated for at least 30 minutes to assure that the sample is representative.

Responsibilities

- the contractor shall drain a small sample of the heat transfer fluid from the system for testing. The sample shall be sent to a lab for analysis and a copy of the test report sent to the owner or to his appointed representative.

Lab Tests

Test No. 1 - Reserve Alkalinity

- determine the amount of alkaline inhibitors present in the antifreeze solution by means of a reserve alkalinity test.

The test should be conducted in accordance with ASTM D 1121-72 Reserve Alkalinity of Engine Antifreeze, Antirusts and Coolants:

- check the specific antifreeze manufacturer for the desired reserve alkalinity and the method of restoring the solution to the required level;
- Example: Dow recommends adding dipotassium phosphate to the glycol solution if the reserve alkalinity falls below 9.0. The level should be maintained in the range of 10 to 12.

Reserve Alkalinity as measured in test __________

Test No. 2 - Concentration Ratio

- determine the antifreeze to water concentration of the solution:
  - the concentration may be obtained with a hydrometer, refractometer or by the ASTM E 203 - 75 - Water using Karl Fischer Reagent.

Concentration as measured in test - _________ % antifreeze
- _________ % water

Test No. 3 - pH Level

- determine the acidity of the solution in accordance with ASTM D 1613 - 66 (Reapproved 1972) - Acidity in volatile solvents and chemical intermediates used in paint, varnish, lacquer and related products.

pH level as measured in test __________

4. Control System Tests

Preparations

- obtain a copy of the temperature sensor characteristic curve from the manufacturer (resistance vs. temperature);
- obtain variable resistors which can be substituted for the system temperature sensors. These resistors can either have a built-in means of reading the set resistance or can be standard potentiometers from which the resistance can be determined using an accurate resistance meter. The variable resistors should have a range of 0 to 100,000 ohms;
- the controller should be wired for power.

Responsibilities

- the tests shall be the responsibility of the contractor;
- all testing will be witnessed by the owner or by his appointed representative and the design consultant.

Scheduling

- the tests will be performed following the installation of the controller and temperature sensors;
- the tests may be conducted at any level of solar insolation and system flow.

Test No. 1 - Fail Safe Operation

- switch off the electrical power to all pumps and/or control valves;
- verify that the controller is receiving electrical power;

- test the controller for short circuit protection (zero resistance). With a test light on the leads to the pump or to the control valve it operates, short circuit the temperature sensor leads. The test light should not come on;

- test the controller for open circuit protection (infinite resistance). With a test light on the leads to the pump or to the control valve it operates, open circuit the temperature sensor leads. The test light should not come on.

Test No. 2 - Differential Setting

- switch off the electrical power to pumps and/or control valves;

- set the differential controller for the recommended temperature differential;

Specified temperature differential on 10 °C
off 3 °C

- follow the specified procedure and record the readings in the chart on the following page;

- disconnect collector and tank sensors at the controller and substitute with appropriate variable resistors. The resistors can be connected to the sensor terminals at the controller;

- from the temperature sensor characteristic curve, determine the resistance associated with 5°C absolute temperature;

- dial this resistance into the variable resistor on the output to the tank sensor. Record the resistance;

- with the controller set in the automatic position, gradually change the resistance on the collector variable resistor until an output is measured at the controller output terminals (to pump or control valve). Record the indicated resistance;

- vary the resistance until there is no longer an output at the controller output terminals. Record the indicated resistance;

- calculate the differential resistance and, from the temperature *sensor characteristic curve, determine the temperature differential;*

- compare this with the original setting of differential temperature using the following equation:

$$\frac{100\% \times \text{differential temperature setting} - \text{differential temperature}}{\text{differential temperature setting}} = \underline{\qquad}\%$$

- reset the tank variable resistor for the resistance associated with a 15°C absolute temperature and repeat the above procedure.

Tank Sensor = 5°C

Tank Sensor	Collector Sensor	Differential	Temperature Differential	% Temperature Difference
_____ohms	on: _____ohms	_____ohms	_______°C	_________
	off: _____ohms	_____ohms	_______°C	_________

Tank Sensor = 15°C

Tank Sensor	Collector Sensor	Differential	Temperature Differential	% Temperature Difference
_____ohms	on: _____ohms	_____ohms	_______°C	_________
_____ohms	off: _____ohms	_____ohms	_______°C	_________

- if the percent temperature difference is substantial (more than ten percent), for any of the four tests, adjust the controller setting and repeat the above test.

Thermistor Resistance versus Temperature

PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032
Ω @25°C	2252	3000	5000	10.000	30.000
BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE
END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED
TEMP. °C	RESISTANCE Ω				
—80	1660K	2211K	3685K	3558K	
79	1518K	2022K	3371K	3296K	
78	1390K	1851K	3086K	3055K	
77	1273K	1696K	2827K	2833K	
76	1167K	1555K	2592K	2629K	
75	1071K	1426K	2378K	2440K	
74	982.8K	1309K	2182K	2266K	
73	902.7K	1202K	2005K	2106K	
72	829.7K	1105K	1843K	1957K	
71	763.1K	1016K	1695K	1821K	
—70	702.3K	935.4K	1560K	1694K	
69	646.7K	861.4K	1436K	1577K	
68	595.9K	793.7K	1323K	1469K	
67	549.4K	731.8K	1220K	1369K	
66	506.9K	675.2K	1126K	1276K	
65	467.9K	623.3K	1039K	1190K	
64	432.2K	575.7K	959.9K	1111K	
63	399.5K	532.1K	887.2K	1037K	
62	369.4K	492.1K	820.5K	968.4K	
61	341.8K	455.3K	759.2K	904.9K	
—60	316.5K	421.5K	702.9K	845.9K	
59	293.2K	390.5K	651.1K	791.1K	
58	271.7K	361.9K	603.5K	740.2K	
57	252.0K	335.7K	559.7K	692.8K	
56	233.8K	311.5K	519.4K	648.8K	
55	217.1K	289.2K	482.2K	607.8K	
54	201.7K	268.6K	447.9K	569.6K	
53	187.4K	249.7K	416.3K	534.1K	
52	174.3K	232.2K	387.1K	501.0K	
51	162.2K	216.0K	360.2K	470.1K	
—50	151.0K	201.1K	335.3K	441.3K	
49	140.6K	187.3K	312.3K	414.5K	
48	131.0K	174.5K	291.0K	389.4K	
47	122.1K	162.7K	271.3K	366.0K	
46	113.9K	151.7K	253.0K	344.1K	
45	106.3K	141.6K	236.2K	323.7K	
44	99.26K	132.2K	220.5K	304.6K	
43	92.72K	123.5K	205.9K	286.7K	
42	86.65K	115.4K	192.5K	270.0K	
41	81.02K	107.9K	180.0K	254.4K	
—40	75.79K	101.0K	168.3K	239.8K	884.6K
39	70.93K	94.48K	157.5K	226.0K	830.9K
38	66.41K	88.46K	147.5K	213.2K	780.8K
37	62.21K	82.87K	138.2K	201.1K	733.9K
36	58.30K	77.66K	129.5K	189.8K	690.2K
35	54.66K	72.81K	121.4K	179.2K	649.3K
34	51.27K	68.30K	113.9K	169.3K	611.0K
33	48.11K	64.09K	106.9K	160.0K	575.2K
32	45.17K	60.17K	100.3K	151.2K	541.7K
31	42.42K	56.51K	94.22K	143.0K	510.4K
—30	39.86K	53.10K	88.53K	135.2K	481.0K
29	37.47K	49.91K	83.22K	127.9K	453.5K
28	35.24K	46.94K	78.26K	121.1K	427.7K
27	33.15K	44.16K	73.62K	114.6K	403.5K
26	31.20K	41.56K	69.29K	108.6K	380.9K
25	29.38K	39.13K	65.24K	102.9K	359.6K
24	27.67K	36.86K	61.45K	97.49K	339.6K
23	26.07K	34.73K	57.90K	92.43K	320.9K
22	24.58K	32.74K	54.58K	87.66K	303.3K
21	23.18K	30.87K	51.47K	83.16K	286.7K
—20	21.87K	29.13K	48.56K	78.91K	271.2K
19	20.64K	27.49K	45.83K	74.91K	256.5K
18	19.48K	25.95K	43.27K	71.13K	242.8K
17	18.40K	24.51K	40.86K	67.57K	229.8K
16	17.39K	23.16K	38.61K	64.20K	217.6K
15	16.43K	21.89K	36.49K	61.02K	206.2K
14	15.54K	20.70K	34.50K	58.01K	195.4K
13	14.70K	19.58K	32.63K	55.17K	185.2K
12	13.91K	18.52K	30.88K	52.48K	175.6K
11	13.16K	17.53K	29.23K	49.94K	166.6K
—10	12.46K	16.60K	27.67K	47.54K	158.0K
9	11.81K	15.72K	26.21K	45.27K	150.0K
8	11.19K	14.90K	24.83K	43.11K	142.4K
7	10.60K	14.12K	23.54K	41.07K	135.2K
6	10.05K	13.39K	22.32K	39.14K	128.5K
5	9534	12.70K	21.17K	37.31K	122.1K
4	9046	12.05K	20.08K	35.57K	116.0K
3	8586	11.44K	19.06K	33.93K	110.3K
2	8151	10.86K	18.10K	32.37K	104.9K
—1	7741	10.31K	17.19K	30.89K	99.80K
0	7355	9796	16.33K	29.49K	94.98K
+1	6989	9310	15.52K	28.15K	90.41K
2	6644	8851	14.75K	26.89K	86.09K
3	6319	8417	14.03K	25.69K	81.99K
4	6011	8006	13.34K	24.55K	78.11K
5	5719	7618	12.70K	23.46K	74.44K
6	5444	7252	12.09K	22.43K	70.96K
7	5183	6905	11.51K	21.45K	67.66K
8	4937	6576	10.96K	20.52K	64.53K
9	4703	6265	10.44K	19.63K	61.56K
+10	4482	5971	9951	18.79K	58.75K
11	4273	5692	9486	17.98K	56.07K
12	4074	5427	9046	17.22K	53.54K
13	3886	5177	8628	16.49K	51.13K
14	3708	4939	8232	15.79K	48.84K
15	3539	4714	7857	15.13K	46.67K
16	3378	4500	7500	14.50K	44.60K
17	3226	4297	7162	13.90K	42.64K
18	3081	4105	6841	13.33K	40.77K
19	2944	3922	6536	12.79K	38.99K
+20	2814	3748	6247	12.26K	37.30K
21	2690	3583	5972	11.77K	35.70K
22	2572	3426	5710	11.29K	34.17K
23	2460	3277	5462	10.84K	32.71K
24	2354	3135	5225	10.41K	31.32K
25	2252	3000	5000	10.00K	30.00K
26	2156	2872	4787	9605	28.74K
27	2064	2750	4583	9227	27.54K
28	1977	2633	4389	8867	26.40K
29	1894	2523	4204	8523	25.31K
+30	1815	2417	4029	8194	24.27K
31	1739	2317	3861	7880	23.28K
32	1667	2221	3702	7579	22.33K
33	1599	2130	3549	7291	21.43K
34	1533	2042	3404	7016	20.57K
35	1471	1959	3266	6752	19.74K
36	1412	1880	3134	6500	18.96K
37	1355	1805	3008	6258	18.21K
38	1301	1733	2888	6026	17.49K
+39	1249	1664	2773	5805	16.80K

Thermistor Resistance Versus Temperature

PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032
Ω @25°C	2252	3000	5000	10.000	30.000
BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE
END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED
TEMP. °C	RESISTANCE Ω				
+40	1200	1598	2663	5592	16.15K
41	1152	1535	2559	5389	15.52K
42	1107	1475	2459	5193	14.92K
43	1064	1418	2363	5006	14.35K
44	1023	1363	2272	4827	13.80K
45	983.8	1310	2184	4655	13.28K
46	946.2	1260	2101	4489	12.77K
47	910.2	1212	2021	4331	12.29K
48	875.8	1167	1944	4179	11.83K
49	842.8	1123	1871	4033	11.39K
+50	811.3	1081	1801	3893	10.97K
51	781.1	1040	1734	3758	10.57K
52	752.2	1002	1670	3629	10.18K
53	724.5	965.0	1608	3504	9807
54	697.9	929.6	1549	3385	9450
55	672.5	895.8	1493	3270	9109
56	648.1	863.3	1439	3160	8781
57	624.8	832.2	1387	3054	8467
58	602.4	802.3	1337	2952	8166
59	580.9	773.7	1290	2854	7876
+60	560.3	746.3	1244	2760	7599
61	540.5	719.9	1200	2669	7332
62	521.5	694.7	1158	2582	7076
63	503.3	670.4	1117	2497	6830
64	485.8	647.1	1079	2417	6594
65	469.0	624.7	1041	2339	6367
66	452.9	603.3	1006	2264	6149
67	437.4	582.6	971.1	2191	5940
68	422.5	562.8	938.0	2122	5738
69	408.2	543.7	906.3	2055	5545
+70	394.5	525.4	875.7	1990	5359
71	381.2	507.8	846.4	1928	5180
72	368.5	490.9	818.3	1868	5007
73	356.2	474.7	791.2	1810	4842
74	344.5	459.0	765.1	1754	4682
75	333.1	444.0	740.0	1700	4529
76	322.3	429.5	715.9	1648	4381
77	311.8	415.6	692.7	1598	4239
78	301.7	402.2	670.3	1549	4102
79	292.0	389.3	648.8	1503	3970
+80	282.7	376.9	628.1	1458	3843
81	273.7	364.9	608.2	1414	3720
82	265.0	353.4	588.9	1372	3602
83	256.7	342.2	570.4	1332	3489
84	248.6	331.5	552.6	1293	3379
85	240.9	321.2	535.4	1255	3273
86	233.4	311.3	518.8	1218	3172
87	226.2	301.7	502.8	1183	3073
88	219.3	292.4	487.4	1149	2979
89	212.6	283.5	472.6	1116	2887
+90	206.1	274.9	458.2	1084	2799
91	199.9	266.6	444.4	1053	2714
92	193.9	258.6	431.0	1023	2632
93	188.1	250.9	418.2	994.2	2552
94	182.5	243.4	405.7	966.3	2476
95	177.1	236.2	393.7	939.3	2402
96	171.9	229.3	382.1	913.2	2331
97	166.9	222.6	370.9	887.9	2262
98	162.0	216.1	360.1	863.4	2195
99	157.3	209.8	349.7	839.7	2131
+100	152.8	203.8	339.6	816.8	2069
101	148.4	197.9	329.8	794.6	2009
102	144.2	192.2	320.4	773.1	1950
103	140.1	186.8	311.3	752.3	1894
104	136.1	181.5	302.5	732.1	1840
105	132.3	176.4	294.0	712.6	1788
106	128.6	171.4	285.7	693.6	1737
107	125.0	166.7	277.8	675.3	1688
108	121.6	162.0	270.1	657.5	1640
109	118.2	157.6	262.6	640.3	1594
+110	115.0	153.2	255.4	623.5	1550
111	111.8	149.0	248.4	607.3	1507
112	108.8	145.0	241.6	591.6	1465
113	105.8	141.1	235.1	576.4	1425
114	103.0	137.2	228.7	561.6	1386
115	100.2	133.6	222.6	547.3	1348
116	97.6	130.0	216.7	533.4	1311
117	95.0	126.5	210.9	519.9	1276
118	92.5	123.2	205.3	[illegible]	1241
119	90.0	119.9	199.9	[illegible]	[illegible]
+120	87.7	[illegible]	194.7	[illegible]	1176
121	85.4	113.8	189.6	469.8	1145
122	83.2	110.8	184.7	458.2	1114
123	71.1	107.9	179.9	446.9	1085
124	79.0	105.2	175.3	435.9	1057
125	77.0	102.5	170.8	425.3	1029
126	75.0	99.9	166.4	414.9	1002
127	73.1	97.3	162.2	404.9	976.3
128	71.3	94.9	158.1	395.1	951.1
129	69.5	92.5	154.1	385.6	926.7
+130	67.8	90.2	150.3	376.4	903.0
131	66.1	87.9	146.5	367.4	880.0
132	64.4	85.7	142.9	358.7	857.7
133	62.9	83.6	139.4	350.3	836.1
134	61.3	81.6	136.0	342.0	815.0
135	59.8	79.6	132.6	334.0	794.6
136	58.4	77.6	129.4	326.3	774.8
137	57.0	75.8	126.3	318.7	755.6
138	55.6	73.9	123.2	311.3	736.9
139	54.3	72.2	120.3	304.2	718.8
+140	53.0	70.4	117.4	297.2	701.2
141	51.7	68.8	114.6	290.4	684.1
142	50.5	67.1	111.9	283.8	667.5
143	49.3	65.5	109.2	277.4	651.3
144	48.2	64.0	106.7	271.2	635.6
145	47.0	62.5	104.2	265.1	620.3
146	45.9	61.1	101.8	259.2	605.5
147	44.9	59.6	99.40	253.4	591.1
148	43.8	58.3	97.10	247.8	577.1
149	42.8	56.9	94.87	242.3	563.5
+150	41.9	55.6	92.70	237.0	550.2

[illegible]

[illegible]

5. Motor and Pump Test

Preparations - Motor

- single phase motors need not be checked; however, all three phase motors should be checked for proper direction of rotation;
- verify that the motor is fully wired, protected, and ready to operate.

Preparations - Pump

- assure that all valves are in the position required for normal system operation;
- collect the applicable pump curves.

Responsibilities

- the test shall be the responsibility of the contractor;
- all testing will be witnessed by the owner or his appointed representative and by the design consultant.

Scheduling

- the rotation test will be performed following the installation and wiring of the motor and the pump.
- perform the circulation test as soon as the system is filled with liquid.

Direction of Rotation

- with the motor running, observe the end of the pump shaft to verify that it is running in the proper direction;

- if the pump is running backwards, connect the wires in the correct phase sequence.

Motor - Amperage

- with the motor operating, measure the current:

  Measured current __________________

- the current should not exceed eighty percent of the nameplate rating.

Pump - Circulation Test

For each pump in the solar system, repeat this procedure:

- close the pump outlet valve;

- observe the pressures P_{in} and P_{out}. (See Figure 2.1.) The pressure difference across the pump ($P_{out} - P_{in}$) should be the maximum operating pressure for the pump, as specified by the manufacturer, or the zero flow rate pressure from the pump curve.

  Pump No. ___1___

  Outlet valve closed

  P_{in} _______ kPa

  P_{out} _______ kPa

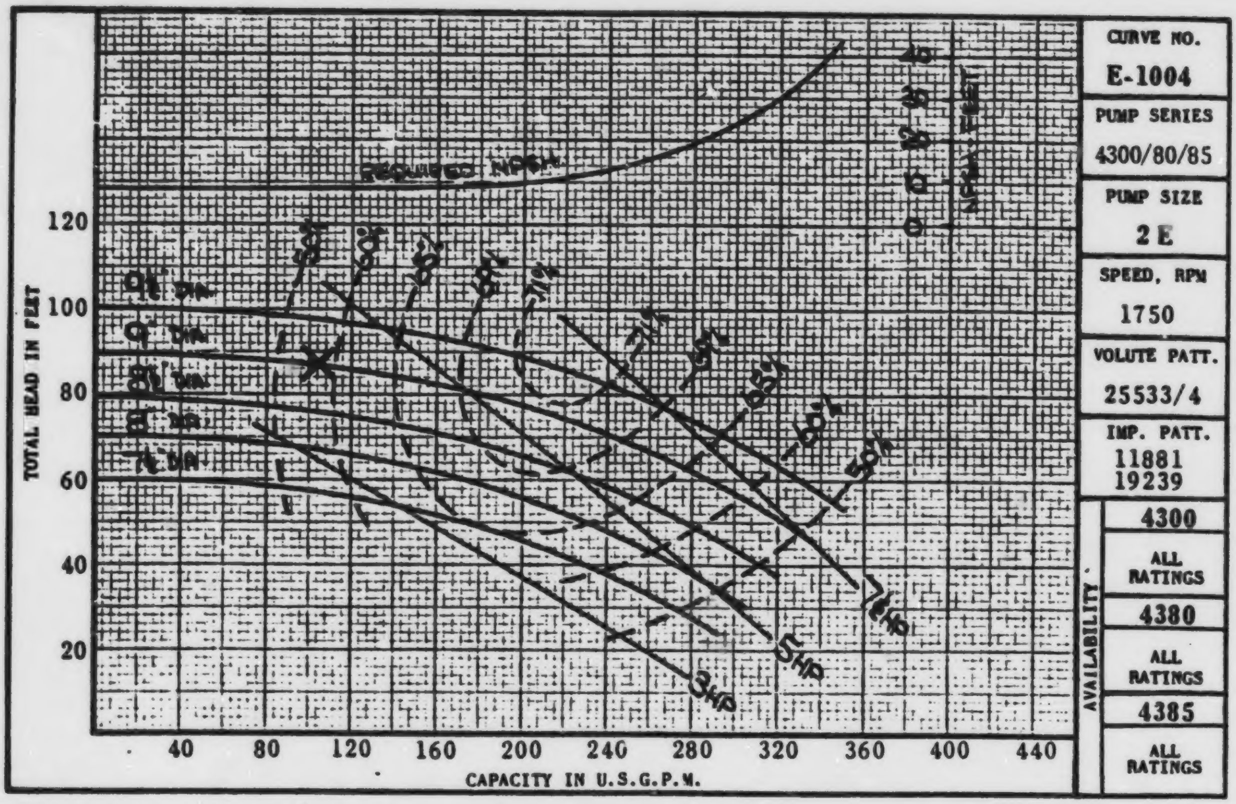
  $P_{out} - P_{in}$ _______ kPa

- slowly, open the pump outlet valve;

- observe the output operating pressure P_{out}. The pump's output pressure should drop and remain at a pressure below the pump's stagnation pressure (P_{out} outlet valve closed). A drop in pressure and then a rise back to the stagnation pressure indicates a blockage in the system.

Outlet valve open	P_{out}	_______	kPa
Pump No. ___2___	P_{in}	_______	kPa
Outlet valve closed	P_{out}	_______	kPa
	$P_{out} - P_{in}$	_______	kPa
Outlet valve open	P_{out}	_______	kPa

ACE ATHLETIC ASSOCIATION
PUMP CURVE
FOR PRIMARY PUMP

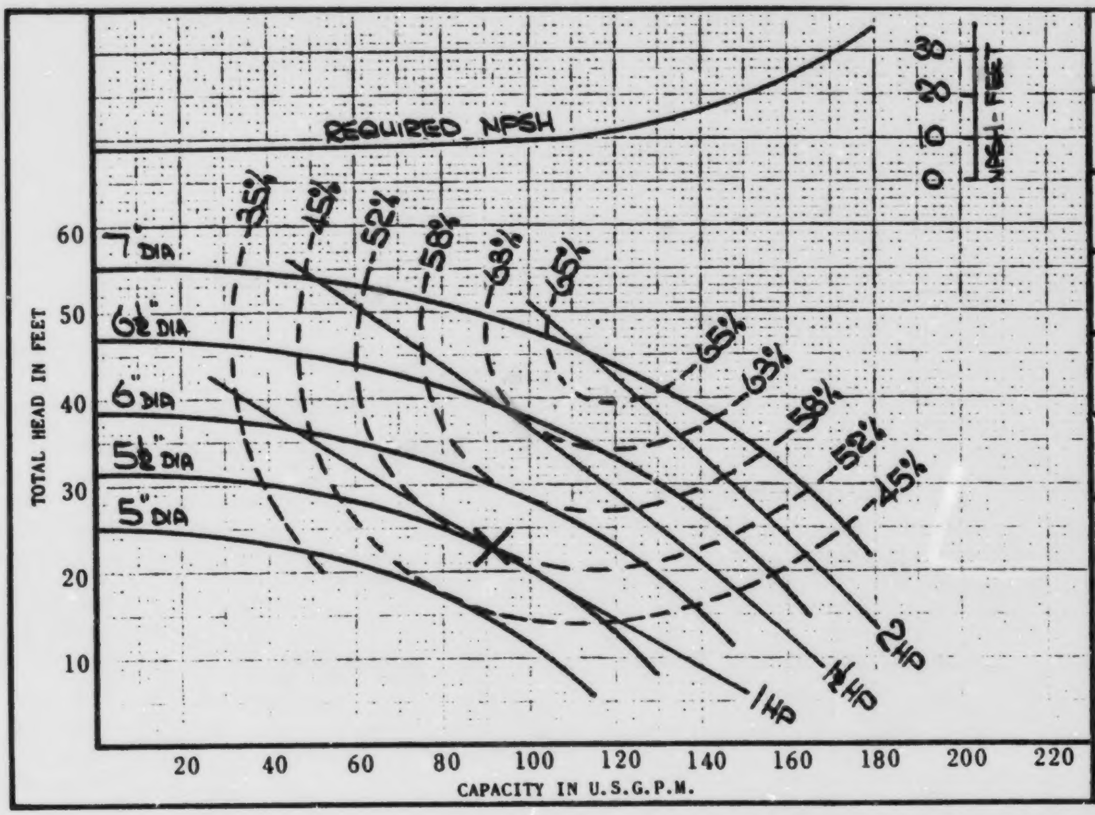


CURVE NO.	E-1004
PUMP SERIES	4300/80/85
PUMP SIZE	2 E
SPEED, RPM	1750
VOLUTE PATT.	25533/4
IMP. PATT.	11881 19239
4300	ALL RATINGS
4380	ALL RATINGS
4385	ALL RATINGS

FORM NO. 3596 *PAGE 1 OF 2* S. A. ARMSTRONG LIMITED, TORONTO, ONTARIO (M4B 2T9)
Litho in Canada

X = operating point

ACE ATHLETIC ASSOCIATION
PUMP CURVE
FOR SECONDARY PUMP



CURVE NO.	**E-1000**
PUMP SERIES	4300/80/85
PUMP SIZE	**2 D**
SPEED, RPM	1750
VOLUTE PATT.	25523/4
IMP. PATT.	11860

AVAILABILITY	
4300	ALL RATINGS
4380	ALL RATINGS
4385	ALL RATINGS

FORM NO. 3595 *PAGE 1 OF 2*
Litho in Canada

S. A. ARMSTRONG LIMITED, TORONTO, ONTARIO (M4B 2T9)

X = operating point

6. Leak Test

- the system should be pressure tested with the working fluid if possible;

- if conditions do not allow the use of the working fluid, an air or dry nitrogen test may be used;

- every liquid loop system shall hold for fifteen minutes;

  (a) without leakage, a water (glycol) pressure at least equal to the maximum pressure to which it may be subjected in service, or

  (b) without a drop in pressure, an air pressure of not less than 700 kPa or the maximum working pressure of the lowest rated component;

- all leaks should be noted and repaired immediately;

- the system should be retested following any repairs to the system.

7. Final Visual Inspection

- check the collector for outgassing:
    - in many instances, condensation forms on the underside of the glazing; however, this should "bake" off after one or two sunny days;
- if the condensation fails to bake off, then the condensation could be the by-product of the gases given off by the collector. In this case, the inside of the collector glazing will have to be cleaned or the glazing will have to be replaced;
- if condensation has fallen onto the absorber surface, an iridescent effect may appear. This will not effect the collector's performance if it is merely the condensate of water; however, if it is from outgassing, the oil residue will have to be removed from the absorber surface to restore the collector's performance. Before attempting to clean the absorber surface, contact the manufacturer of the collector for advice;
- with the pump operating, verify the system flow by observing the flow indicator on the collector loop;
- verify that the system static pressure is within the tolerances of the given design and that this pressure does not exceed the rated pressure of the expansion tank;

Specified static pressure:	primary loop	120	kPa minimum
		150	kPa maximum
	secondary loop	280	kPa minimum
		400	kPa maximum

- verify that all manually operated valves are in the specified position (open or closed) required for normal operation of the system and that they have tags indicating the specified position;

- verify that the heat transfer fluid fill valve is sealed with a dated crimped seal.

8. System Flow Checks

Preliminary Information

- total collector loop flow required: 400 L/min
- obtain a copy of the manufacturer's pump curve for the pump;

Collector Loop Flow Rate

- make sure the system is in an operating mode, with either the:
  - controller in the automatic position on a sunny day,
    or
  - controller in the manual position on an overcast day.
- check the flow indicator to verify that there is flow and that it is in the prescribed direction;
- the following test should be carried out for the pump in the collector loop;
  - measure the pressure differential across the pump;

    Measured pressure differential ________ kPa

  - from the manufacturer's pump curve, determine the operating point for the pump;
  - for this operating point, read off the operating flow rate;

    Flow rate as determined from pump curve ________ L/min

- adjust the flow by the means provided in the system until the flow rate is approximately equal to the specified flow rate;

- record the final operating flow rate:

Final operating flow rate _________ L/min

Collector Bank Flow Verification

- on a sunny day, with the circulation system operating and all balancing valves open, verify that flow exists in all banks. This may be accomplished by observing and recording the collector supply temperature and the bank outlet temperature for each bank of collectors:

collector supply temperature _________ °C
bank number __1__ outlet temperature _________ °C
__2__ _________ °C
__3__ _________ °C
__4__ _________ °C

- if any of the bank outlet temperatures are significantly different from any others, there may be a restriction in the circuit.

COMMISSIONING PROCEDURES

ACE ATHLETIC ASSOCIATION
CLOSED LOOP SYSTEM - DOMESTIC HOT WATER
CAFETERIA AND RECREATION CENTRE

INDEX

1. General Introduction to Commissioning Document
    - Pre-conditions
    - Responsibilities
    - Scheduling

2. Verification of Pump Performance and System Flow Rates
    - Collector Loop Flow Rate
    - Bank Flow Rates

3. Final Flow Adjustment

4. Heat Exchanger Effectiveness

5. Preliminary Thermal Performance Test

1. General Introduction to Commissioning Document

Commissioning is a demonstration by the consultant and the contractor to the owner that the solar system is operating in a safe and efficient manner. The solar system will undergo a series of tests and adjustments to meet or exceed a prescribed level of efficiency.

Pre-conditions

- it is assumed that start-up has been successfully completed;

Responsibilities

- the commissioning will be carried out by the consultant and the contractor in the presence of the owner or his representative.

Scheduling

- the system must have been in operation for a minimum of five days after the final start-up test before the system is commissioned.

2. Verification of Pump Performance and System Flow Rates

Collector Loop Flow Rate

- make sure the system is in an operating mode, with either the:
    - controller in the automatic position on a sunny day,
      or
    - controller in the manual position on an overcast day.
- check the flow indicator to verify that there is flow and that it is in the prescribed direction;
- the following test should be carried out for the pump in the collector loop:
    - measure the operating amperage of the pump with a clamp-on ammeter;

      Measured amperage __________

    - convert amperage to the equivalent horsepower; using the following equation;

      Calculated horsepower __________

$$P = \sqrt{3}\, E\, I \cos\varphi \qquad \text{(three phase)}$$

where:

I = line current, amps
P = power, kW
E = line voltage, volts
$\cos\varphi$ = power factor

	Power Factor, cos φ three phase
1/2 HP or less	.75
1 - 2 HP	.75
2 1/2 - 15 HP	.80

1 HP = .7457 kW

- measure the pressure differential across the pump;

  Measured pressure differential _________ kPa

- from the manufacturer's pump curve, determine the operating point for the pump;

- for this operating point, read off the operating flow rate;

  Flow rate as determined from pump curve _________ L/min

- if the flow rate is not within twenty percent (plus or minus) of the specified flow rate, adjust the flow by the means provided in the system until the flow rate is within the allowable range, and record the new flow settings;

  Final operating flow rate _________ L/min

Bank Flow Rates

- with the system operating, measure the temperature rise across each collector bank;

bank number 1 temperature rise ________ °C
2 ________ °C
3 ________ °C
4 ________ °C

- if the temperature rise across the hottest bank is less than fifty percent greater than the temperature rise across the coldest bank, or within 1°C, and place a dated locking tag on all throttling valves;

- if the temperature rises are not within these limits, carry out the balancing procedures outlined below:

Balancing Procedures

- leave the balancing valve of the bank registering the highest temperature fully open - reduce the flow through the other banks by partially and judiciously closing the other balancing valves;

- leave the system to stabilize for about ten minutes and observe the bank outlet temperatures;

- repeat this process until the temperature rise across the hottest bank is less than fifty percent greater than the temperature rise across the coldest bank, or within 1°C, and place a dated locking tag on all throttling valves.

3. Final Flow Adjustment

- with the collector flows balanced, a final adjustment of the overall flow rate is made and the value is recorded;

- place a dated locking tag on the system throttling valve;

Note: A final flow adjustment is mandatory whenever the collector bank flows are altered.

Record the following:

Test Date: Time: Hours:

Total Collector Loop Flow ______________ L/min

bank number	1	temperature rise	________ °C
	2		________ °C
	3		________ °C
	4		________ °C

4. Heat Exchanger Effectiveness

- the test should be carried out using the normal hot water draw on the load side;

- the design hot water draw rate is 350 L/min;

- record the hot water draw rate during the test, if possible: _______ L/min

- with the pumps operating, measure and record the following temperatures: (Note the schematic of the heat exchanger on the following page which indicates where to measure the required temperatures.)

$T_{P(in)}$ - primary side inlet _____°C

$T_{P(out)}$ - primary side outlet _____°C

$T_{S(in)}$ - secondary side inlet _____°C

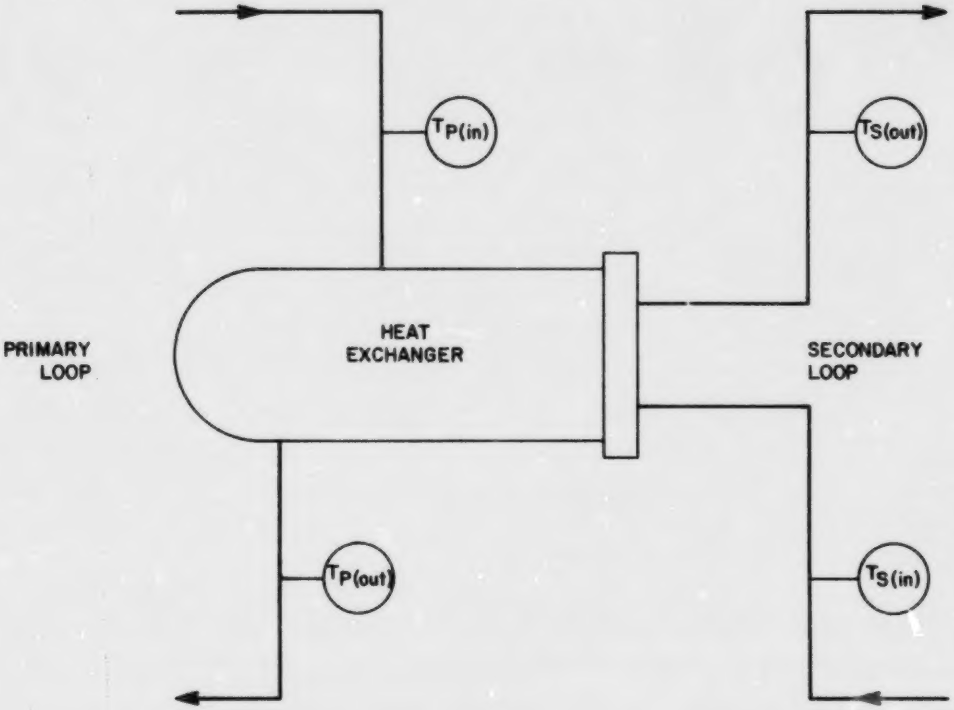
$T_{S(out)}$ - secondary side outlet _____°C

- calculate the heat exchanger effectiveness (E) using the following equation: (Note: counter flow heat exchanger, minimum heat capacity rate on the secondary side)

$$E = \frac{T_{S(out)} - T_{S(in)}}{T_{P(in)} - T_{S(in)}}$$

Heat exchanger effectiveness ______________

A problem is indicated if the effectiveness is not within the following range: .7, .85.



Schematic of Heat Exchanger

5. Preliminary Thermal Performance Test

The preliminary thermal performance test is undertaken in order to assess the operation of the solar system as a whole, and to compare the results with the performance that should be expected based on the collector manufacturer's claimed performance.

Perform the thermal performance test on a sunny day between 11:00 a.m. and 1:00 p.m. The storage temperature must be well below the maximum.

- Record the following measurements:

T_A - outdoor ambient temperature ________ °C

$T_{C(out)}$ - collector return temperature ________ °C

$T_{C(in)}$ - collector supply temperature ________ °C

F_S - total collector loop flow rate ________ L/min

I - solar insolation ________ W/m^2*

* The solar insolation should be measured using a hand held pyranometer. Measure the insolation during the test period. Hold the pyranometer against the surface of the collector when taking measurements.

Airport weather stations may be able to supply current solar insolation levels.

- determine the density and the specific heat of the collector heat transfer fluid:

where: c_p is the specific heat in J/kg°C

$$= \frac{\%\ \text{water} \times 1\ \text{kg/L} + \%\ \text{glycol} \times c_p\ \text{glycol}}{100} = \_\_\_\_\_\_\ \text{kg/L}$$

$$= \frac{\%\ \text{water} \times 4190\ \text{J/kg}^{o}\text{C} \times \%\ \text{glycol} \times c_p\ \text{glycol}}{100} = \_\_\_\_\_\_\ \text{J/kg}^{o}\text{C}$$

- calculate the temperature rise across the collector:

$$T = T_{C(out)} - T_{C(in)} = \_\_\_\_\_\_\ ^{o}\text{C}$$

- determine the heat gain:

where: ρ is the density in kg/L

$$Q = \frac{F_S \times \rho \times T \times c_p}{60} = \_\_\_\_\_\_\ \text{W}$$

$$\frac{\text{L}}{\text{min}} \times \frac{\text{kg}}{\text{L}} \times \frac{\text{min}}{\text{s}} \times {}^{o}\text{C} \times \frac{\text{J}}{\text{kg}\ ^{o}\text{C}} \times \frac{\text{W}}{\text{J/s}}$$

- determine the heat gain per unit of collector area:

$$q = Q/A$$
$$= \_\_\_\_\_\_\ \text{W/m}^2$$

- the efficiency is then:

  $$\frac{q}{I} \times 100 = \_\_\_\_\_\_\_\_ \%$$

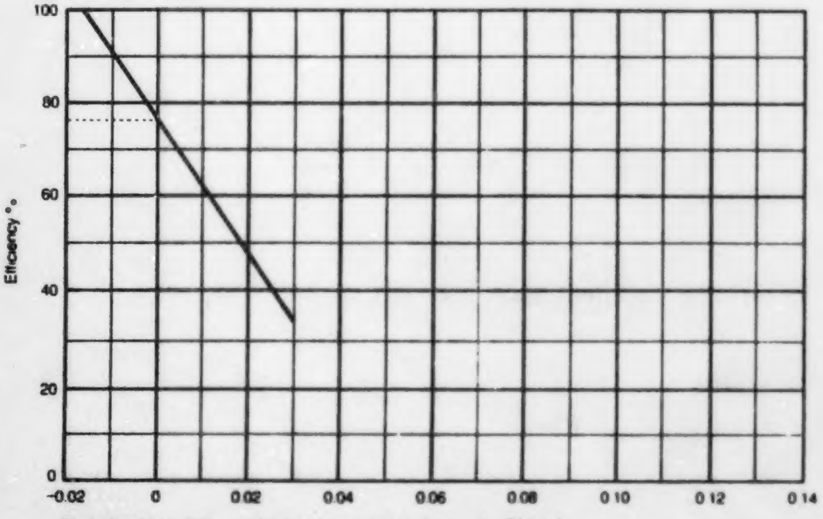
- determine the manufacturer's claimed efficiency, for the given conditions, for:

  $$\text{Operating point} = \frac{T_{C(in)} - T_A}{I} \qquad \text{(parallel operation)}$$

- read the efficiency from the manufacturer's performance curve for this operating point.

Since the measured efficiency includes line losses, it can be expected to be slightly lower than the claimed efficiency for the collectors alone. However, the measured efficiency should not be more than twenty percent lower than the predicted value.

Collector Efficiency Curve



Efficiency curve is based on gross area.

OPERATIONAL MONITORING DOCUMENT

ACE ATHLETIC ASSOCIATION
CLOSED LOOP SYSTEM - DOMESTIC HOT WATER
CAFETERIA AND RECREATION CENTRE

INDEX

1. General System Description

2. System Operation

3. Introduction to Operational Monitoring

4. Operational Monitoring Procedures
    - Daily Operational Checklist
        - Pumps
        - System Pressures
        - System Temperatures
        - General Overview
    - Monthly Operational Schedule
    - Semi-Annual Operational Maintenance Schedule
        - Fluid Quality - Closed Loop Glycol System
        - Heat Exchanger Effectiveness
        - Sensor Calibration Check
        - Preventative Maintenance

1. General System Description

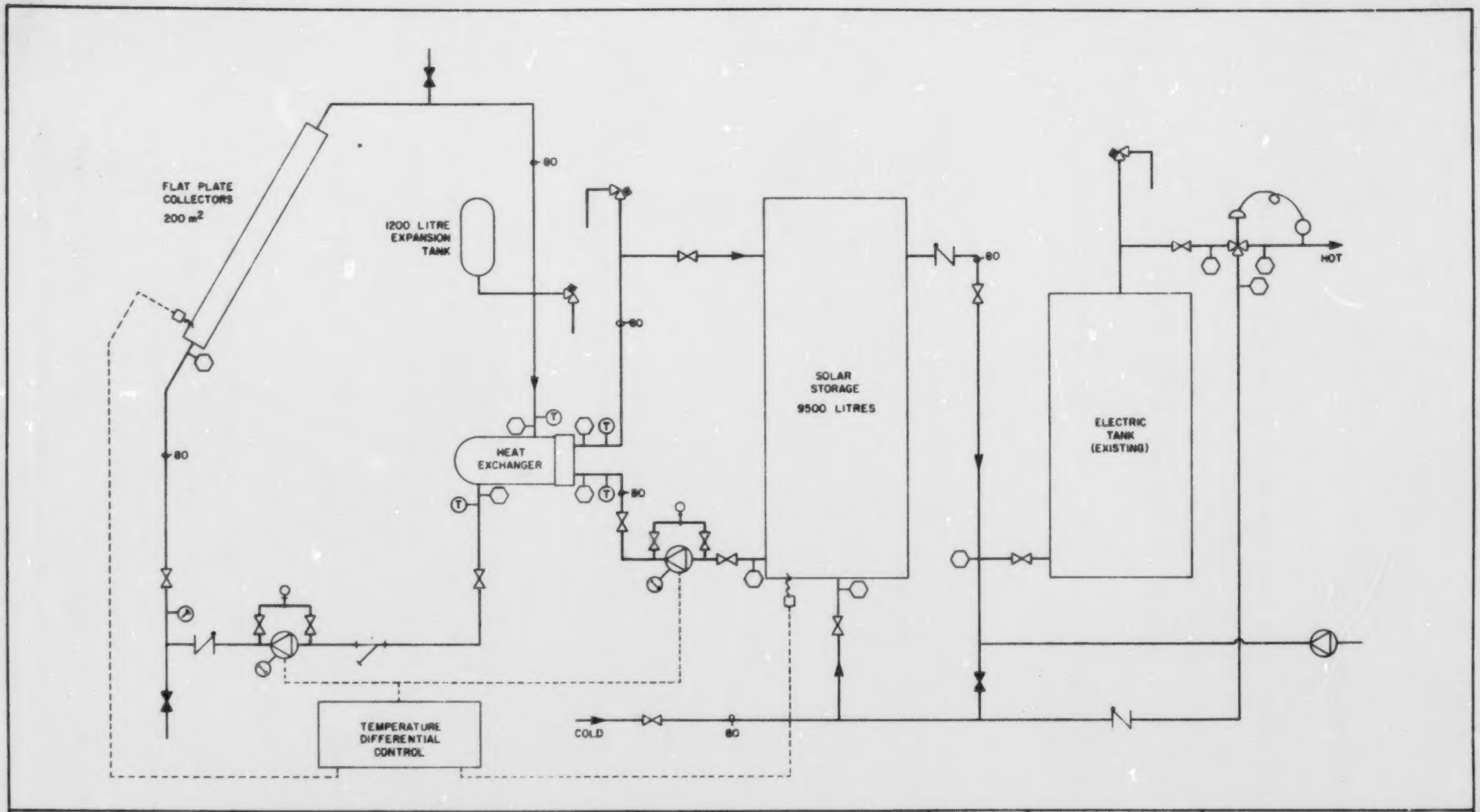
This solar system is designed to heat 350 litres of water per minute. This hot water will be used in both the cafeteria and the recreation centre. Previously, all the water was heated electrically. The solar system will decrease the electric water heating cost by approximately eighty percent.

Note the schematic of the solar hot water system. The system is made up of two major loops; the primary loop and the secondary loop.

The primary loop is a closed loop of piping containing glycol. The primary loop pump circulates the glycol through the collectors, where it is heated, and then through the heat exchanger, where the heat from the glycol is transferred to the water in the secondary loop. An expansion tank and pressure relief valve are in the primary loop to allow for expansion of the glycol if the temperature rises dramatically. A gate valve and strainer are upstream from the pump, and a gate valve and check valve are downstream. The gate valves are needed to isolate the pump from the rest of the system, if required. The check valve is to prevent backflow. Two gate valves; one at the top of the loop and the other at the bottom, are used to drain the glycol or to bleed off air. Their normal position is closed.

The secondary loop contains the water that is being heated. Cold water flows into the solar storage tank (flow is controlled by a gate valve). It then is pumped (again, the pump can be isolated by two gate valves) from the storage tank through the heat exchanger where it is heated by the glycol from the primary loop. It flows back into the solar storage tank. Note the pressure relief valve.

Hot water from the solar storage tank flows into the original electric heating tank along with recirculated hot water coming back from the cafeteria and recreation centre. A check valve prevents backflow into the solar storage tank and gate valves control the flow. If the water in the tank is at a temperature less than 60°C, it is heated electrically to that temperature. If, for any reason, the solar system must be shut down, cold


FLAT PLATE COLLECTORS 200 m^2
1200 LITRE EXPANSION TANK
80
HEAT EXCHANGER
SOLAR STORAGE 9500 LITRES
ELECTRIC TANK (EXISTING)
HOT
COLD
TEMPERATURE DIFFERENTIAL CONTROL

LEGEND

⊖ EVENT COUNTER

⊘ FLOW INDICATOR

⊘ RUN TIME METER

⬡ PETERSON PLUG

Ⓣ TEMPERATURE PROBE

DATE	AUG 1982
DESIGNED	S B
DRAWN	C H
CHECKED	J R

ACME ASSOCIATES
Engineers / Ingénieurs

ACE ATHLETIC ASSOCIATION

Solar Water Heating Facility --A

Schematic with Instrumentation

SCALE	PROJECT NO.	DWG. NO.	REV
N T S	1458-81	4	

"SYSTEM A"

water can be directly brought into the electric heater by opening the normally closed gate valve. If the water coming out of the auxiliary heater is too hot (greater than 60°C), cold water is mixed in to lower the temperature.

2. System Operation

The primary and secondary loops circulate if there is enough available solar energy. A temperature differential control turns the system on and off. The controller compares the temperature of the collector plates to the temperature of the water in the solar storage tank. If the collectors are 10°C warmer than the storage tank, the two pumps will be activated. When the differential drops down below 3°C, the pumps will be shut off.

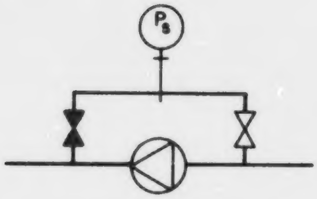
The instrumentation is noted on the schematic. The instruments are needed to monitor the system to make sure it is operating correctly and efficiently. There is an arrangement of two gate valves and a pressure meter around each pump to measure the pressure in, the pressure out and the static pressure. There is also a run time meter on each pump. An event counter is installed on the differential controller to count the number of on - off cycles of the solar system. A flow indicator is situated in the primary flow loop. Temperature probes are installed on the lines in and out of the heat exchanger. Peterson Plugs, in which temperature and pressure probes can be inserted, are positioned as indicated.

In order to follow the operational monitoring schedule, the following measurements must be understood:

- number of cycles:	During the course of a day, the solar system is turned on (pumps on) by the control system when sufficient solar energy is available. When the amount of energy drops to the point where operating the system is no longer practical, the controller turns off (pumps off) the solar system. Every

time the controller turns the system on or off, an "event" is counted on the "event counter". It is important that the controller turns the pumps on and off at the appropriate conditions and, therefore, does not cause the system to cycle excessively. To verify that the controller is working properly, the "number of events" for a period are checked.

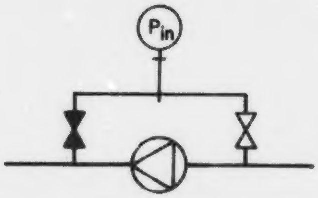
- system static pressure:



PUMPS OFF

The static pressure is the pressure of the liquid in the piping system with the pumps off. The static pressure will be measured in both the primary loop (glycol) and the secondary loop (water). The procedure is the same for both cases. With the pumps off and the gate valve just down stream from the pressure gauge closed, the pressure gauge measures the static pressure.

- inlet pump pressure:



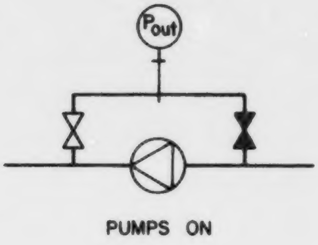
PUMPS ON

The inlet pressure is the pressure of the liquid in the piping system just upstream of the pump when it is operating.

The inlet pressure will be measured in both the primary glycol loop and the secondary water loop. The procedure is the same for both cases. With the pumps on and the gate valve just downstream from the pressure gauge closed, measure the inlet pressure.

- outlet pump pressure:

The outlet pressure is the pressure of the liquid in the piping system just downstream of the pump when it is operating.



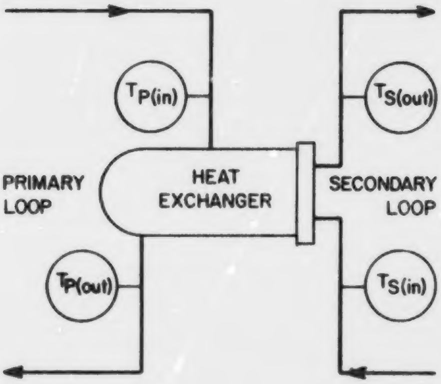
The outlet pressure will be measured in both the primary glycol loop and the secondary water loop. The procedure is the same for both cases. With the pumps on and the gate valve just upstream from the pressure gauge closed, the pressure gauge measures the outlet pressure.

- pump run time:

The run time meter attached to each pump clocks the time the pump is operating. This information is used to ensure that the system is operating close to the expected amount of time. Note: The run time meters cannot be reset so the **additional** hours over a period must be calculated.

- temperatures:

There are several permanently installed temperature probes with a digital readout:



- temperature of glycol/water mixture after it has been heated by the collectors (note: in this system, it is equivalent to $T_{P(in)}$),
- temperature of glycol/water mixture before it has been heated by the collectors (note: in this system, it is equivalent to $T_{P(out)}$),

- temperature of the glycol/water mixture before entering heat exchanger, $T_{P(in)}$,
- temperature of the glycol/water mixture after leaving the heat exchanger, $T_{P(out)}$,
- temperature of water in the secondary loop before entering the heat exchanger, $T_{S(in)}$,
- temperature of water in the secondary loop after leaving the heat exchanger, $T_{S(out)}$,

- system alarms:	There are no system alarms currently installed in the system.

3. Introduction to Operational Monitoring

The prime purpose of operational monitoring is to detect a decrease in the solar system performance. This is done by regularly comparing certain indicators, such as temperatures, pressures and pump run times with those specified in the design and commissioning process. A change in these indicators to outside the design range means that the system has an operational problem. Identifying operational problems or system breakdowns as soon as possible is important in reducing damage to the system, and will also maximize the energy output of the solar system. Early detection of problems will also increase the life of the system, and keep operating and maintenance costs to a minimum.

Checks of instrument readings and verifications of the operation or condition of component equipment are conducted on a set of schedules as follows:

- daily,
- monthly, and
- semi-annually or yearly.

4. Operational Monitoring Procedures

Daily Operational Checklist

To ensure that no major malfunction of the solar system has occurred, the following questions should be considered daily. If the answer to any of the questions is "no", a problem has been detected. To determine the cause of the problem and the required action, see the Operator's Troubleshooting Guide.

Pumps

1. If the weather is sunny, or partially sunny, are the pumps operating?
2. If there is no sun, are the pumps off?

3. If the pumps are operating, is the period of operation reasonable? A problem is indicated if the event counter indicates more than 10 cycles per day. (In one cycle, the system turns on and then off, therefore, 10 cycles per day equals 20 events per day).

System Pressures

4. Is the system static pressure within the acceptable range?
(acceptable range: primary loop 120 kPa to 150 kPa
secondary loop 280 kPa to 400 kPa)
5. If the pumps are operating, is the change in pressure across each pump in the specified range? (low, high)
(specified range ($P_{out}-P_{in}$):
primary loop 245 kPa to 265 kPa
secondary loop 43 kPa to 52 kPa)
6. If the pumps are operating, is the discharge pressure relatively constant for each pump? (maximum deviation = 15 kPa)

System Temperatures

7. If the pumps are operating, is the rise in temperature between "storage to collector" and "collector to storage" within the specified range? (acceptable rise in temperature: 2 °C to 10 °C).

General Overview

8. Does the status of all system alarms indicate normal system operation?
9. Have the pressure relief valves remained closed?
10. Are the vibration and noise levels normal?
11. Is the temperature of all mechanical equipment normal? (no overheating)

Monthly Operational Schedule

Every month a more detailed version of the "daily checks" will be performed and recorded in the chart shown on the following page. This procedure will provide an historical record of the solar system's performance as well as a closer examination of the system to check for possible problems. The monthly checks should be done on a day when solar energy is available and the system is cycling. Use the following procedure to obtain the values for the chart.

(a) Fill in general information; name, date, time, weather description and outside temperature.

(b) For each pump module:

Read and record the pump run time. Subtract the previous month's reading to find the monthly pump run time. Compare this with the expected value for the month. Being high or low may be a result of abnormal weather, but may also be an indication of problems.

Read and record the system static pressure (P_S), the pump discharge pressure (P_{out}), and the pump suction pressure (P_{in}).

Calculate and record the pressure difference across the pump ($P_{out} - P_{in}$).

(c) Read and record the following temperatures:

- Primary circuit heat exchanger: in	$T_{P(in)}$
- Primary circuit collector: feed	$T_{P(out)}$
- Secondary circuit heat exchanger: in	$T_{S(in)}$
- Secondary circuit heat exchanger: out	$T_{S(out)}$
- Solar storage tank: top, bottom	

Calculate ($T_{P(in)} - T_{P(out)}$) and ($T_{S(out)} - T_{S(in)}$). Record.

MONTHLY OPERATIONAL RECORD

Ace Athletic Association

OPERATOR	MONTH	DAY	TIME	WEATHER		PUMP MODULE NO.1							PUMP MODULE NO.2							TEMPERATURES (°C)								TEMPERATURES (°C)								Control Module		Drain Down System	
						Run Time (hrs)			Pressure (kPa)				Run Time (hrs)			Pressure (kPa)				Heat Exchanger No. 1						Solar Storage Tank		Heat Exchanger No. 2						Solar Storage Tank					
																				PRIMARY		SECONDARY						PRIMARY		SECONDARY									
				CLEAR, VARIABLE, or OVERCAST	OUTDOOR TEMP (°C)	TOTAL	MONTHLY	EXPECTED	P_S 120 180	P_{out}	P_{in}	$P_{out} - P_{in}$ 245 265	TOTAL	MONTHLY	EXPECTED	P_S 280 400	P_{out}	P_{in}	$P_{out} - P_{in}$ 45 52	In $T_{P(in)}$	Out $T_{P(out)}$	In $S(in)$	Out $T_{S(out)}$	$T_{P(in)} - T_{P(out)}$ 2° 10°	$T_{S(out)} - T_{S(in)}$	TOP	BOTTOM	In $T_{P(in)}$	Out $T_{P(out)}$	In $T_{S(in)}$	Out $T_{S(out)}$	$T_{P(in)} - T_{P(out)}$	$T_{S(out)} - T_{S(in)}$	TOP	BOTTOM	EVENTS TO DATE	EVENTS FOR MONTH max 900	TIME TO DRAIN (min)	LEVEL (from max)
	Jan							90							90																								
	Feb							120							120																								
	Mar							120							120																								
	Apr							180							180																								
	May							240							240																								
	June							240							240																								
	July							210							210																								
	Aug							210							210																								
	Sept							180							180																								
	Oct							150							150																								
	Nov							120							120																								
	Dec							90							90																								

SYSTEM FAILURE REPORT

OPERATOR	DATE	DESCRIPTION

(d) For each control system module, read and record the number of events to date. Calculate the number of events for the month and compare it to the acceptable range.

(e) Analysis of monthly record:
Compare all readings and calculated values to their specified ranges. If they are outside of the range, consult the Operator's Troubleshooting Guide.

(f) The following preventative maintenance checks should also be performed:

- clean collector glazing where necessary,
- inspect collectors for the following:
  - weep holes full of debris, insects, ice, etc.,
  - deterioration of the absorber plate in the form of discolouration or buckling,
  - permanent condensation on the underside of the collector glazing,
  - temperature variance: a collector that is noticeably cooler or warmer than the others indicates a flow blockage or imbalance (a heat meter reading of the collector surface temperature will do),
- check mounting hardware security and caulking as well as flashing around roof penetrations,
- lubricate pumps, motors and control linkages as required.

Semi-Annual Operational Maintenance Schedule

Semi-annual checks will be conducted each spring and fall. The schedule includes several repeats of test procedures that were done as part of the start-up and commissioning, along with preventative maintenance checks.

Fluid Quality - Closed Loop Glycol System

Three characteristics of the glycol need to be checked semi-annually. If the facilities are not available "in-house", send a 50 ml sample of glycol to an analysis lab.

1. Determine the percentage of glycol to water using a hydrometer, refractometer, or by the ASTM E 203 - 75 - Water using Karl Fischer Reagent. The percentage of glycol determines the freeze point of the solution. The percentage of glycol must be greater than 45 % and less than 55 %. If it is out of the acceptable range, alter it.

2. Determine the pH factor (a measure of the acidity of the solution) in accordance with the ASTM D 1613 - 66 (Reapproved 1972). In order to minimize corrosion, the pH of the solution must be greater than 7 and less than 9 .

3. Determine the reserve alkalinity (a measure of the amount of inhibitor available to react with and neutralize acids formed in the glycol) in accordance with ASTM D 1121-72 Reserve Alkalinity of Engine Antifreeze, Antirusts and Coolants. If the reserve alkalinity is not within the range 10 to 12 , restore it to the required level by using the manufacturer's method.

Heat Exchanger Effectiveness

The test should be carried out using the design hot water draw on the load side.

The design hot water draw rate is _350_ L/min.

With the pumps operating, measure and record the following temperatures;

$T_{P(in)}$ - primary side inlet ______ °C

$T_{P(out)}$ - primary side outlet ______ °C

$T_{S(in)}$ - secondary side inlet ______ °C

$T_{S(out)}$ - secondary side outlet ______ °C

Calculate the heat exchanger effectiveness (E) using the following equation: (Note: counter flow heat exchanger, minimum heat capacity rate on the secondary side)

$$E = \frac{T_{S(out)} - T_{S(in)}}{T_{P(in)} - T_{S(in)}}$$

Heat exchanger effectiveness __________.

A problem is indicated if the effectiveness is not within the following range: _.7_, _.85_.

Sensor Calibration Check

Sensor accuracy can change with time due to the build up of corrosion at the attachment points or the lead connections. Sensor accuracy can also be distorted when it experiences temperature extremes that exceed its design range. Since combined inaccuracies in both the collector and storage sensor inputs can significantly reduce the system performance, sensor calibration checks should be performed semi-annually.

A total of four tests are required:

1. collector sensor at cool temperature (early in morning on cloudy day),
2. collector sensor at hot temperature (mid to late afternoon on sunny day),
3. storage tank sensor at cool temperature,
4. storage tank sensor at hot temperature.

For each test, measure the temperature at the point and the resistance at the control connection. Compare the readings to the temperature-resistance curve supplied by the manufacturer. If there is a discrepancy, corrosion or extreme temperatures could have damaged the sensor or its connections. Check both and replace, if necessary, then repeat the test.

Preventative Maintenance

- Clean filters and strainers
- Cycle or operate valves to assure functioning
- Oil or lubricate components according to the manufacturer's recommendations
- Check charge on expansion tank

TROUBLESHOOTING GUIDE

ACE ATHLETIC ASSOCIATION
CLOSED LOOP SYSTEM - DOMESTIC HOT WATER
CAFETERIA AND RECREATION CENTRE

TROUBLESHOOTING GUIDE

Symptom	Source	Cause	Action
No hot water	Make-up water shut-off valve	Valve closed	Open valve.
	Auxiliary heater	Failed to activate	Check breaker or fuse. Check power to heater. Check fuel supply.
Hot water temperature too low	Hot water thermostat	Thermostat setting too low	Set thermostat higher.
	Auxiliary heater	Not functioning	Check breaker or fuse. Check and repair auxiliary heating unit and fuel supply.
	Temperature modulating valve	Faulty	Repair or replace.
		Temperature set too low	Reset.
Water temperature too high	Hot water thermostat	Thermostat setting too high	Reset.
		Thermostat out of calibration	Recalibrate.
	Temperature modulating valve	Faulty	Repair or replace.
		Temperature set too high	Reset.
Insufficient hot water to load, but solar system seems normal	Auxiliary heater	Auxiliary heater problems	Check auxiliary heater, wiring.
	Valves	Isolation valves improperly closed	Set in proper positions.
	Temperature modulating valve	Improperly adjusted	Check adjustment. Adjust as necessary.
		Faulty	Repair or replace.

Symptom	Source	Cause	Action
Drop in water pressure at both hot and cold outlets	Inlet water pressure	Inlet strainer clogged	Clean basket.
	Pressure reducing valve	Malfunctioning	Check for plugged ports, and proper operation. Clean, repair, or replace.
Drop in water pressure at hot outlets only	Valves	Valve improperly closed	Open manual valves. Check automatic valve operation, repair or replace.
		Jammed check valve	Repair and replace.
	Strainers	Flow restriction	Check and clean.
System does not start or Pumps not running when solar energy available	Power supply	Control switch on "off" position	Turn to "auto" position.
		No power to pump	Check fuses or circuit breaker.
			Check wiring and connections.
		No power to controller	Check fuses or circuit breaker.
			Check wiring and connections.
	Pump	Pump seized	Try turning by hand. Repair or replace.
		Motor failure	Repair or replace.
	Controls	Control failure	Try on "manual". If pump runs suspect control system. (Refer to Troubleshooting Controls)
		Pressure cut offs activated	Rectify cause, reset.
		Temperature cut off activated	If tank temperature below high limit cut off, check control system. (Refer to Troubleshooting Controls)
		Fault in control system	Check control system. (Refer to Troubleshooting Controls)
		Electrical problem	Check line terminal voltage.

Symptom	Source	Cause	Action
Pumps running when no solar energy available	Control system	Control set on "manual"	Set on "automatic".
		Fault in control system	Check control system. (Refer to Troubleshooting Controls)
Pumps cycling excessively	Controls	Incorrect set points	Check set point.
		Fault in control system	Check control system. (Refer to Troubleshooting Controls)
System static pressure low	Charge pressure low	Fluid level low	See "Fluid level low".
	Expansion tank (Diaphram)	Bladder capacity exceeded or diaphram leaking	Inspect for fluid in air chamber, replace expansion tank.
	Expansion tank (Standard)	Inadequate air space	Adjust liquid level.
		Air leak	Find and correct.
Fluid level low	Leak in system	Piping leak	Repair. Replace wet insulation.
		Leak from drain	Close drain tightly, add cap.
		Leak from air vent	Inspect, clean mechanism, repair or replace.
	Pressure relief valve	Relief valve has expelled excess pressure	Find cause for excess pressure; correct. Recharge system to operating pressure.
System static pressure high	Controls	Overtemperature	Find cause. (Refer to Troubleshooting Controls)
	Fluid	System overfilled	Check level.
	Expansion tank	Expansion tank is waterlogged	Check expansion tank liquid level. Check for air leak.
Pump discharge pressure fluctuating	Pump	Cavitation	Find source of air entry, check for restriction on suction side, clean strainer.

Symptom	Source	Cause	Action
Storage temperature decays during periods of no load	Insulation	Damaged or wet	Repair or replace.
	Check valve	Reverse thermosyphoning	Inspect check valve operation. Repair or replace.
Storage temp remains high during high load, little solar	Valves	Isolation valves improperly closed	Set in proper position.
Poor solar energy collection	Collector array	Film on collector glazing	Check for dirt on glazing. Check for condensation and outgassing. Clean glazing.
		New source of shading	Check for new structures growth of trees, etc.
		Flow rate	Check flow rate. Reset to specified flow.
			Check operation of automatic flow control valve. Repair or replace as necessary.
		Flow balance	Check balance of flow through collector banks. Rebalance as necessary.
			Check operation of automatic flow control valves. Repair or replace as necessary.
		Scale forming in collector tubes	Flush collector loop.
	Piping	Insufficient or damaged insulation	Check condition and adequacy of insulation. Repair, replace or add additional insulation.
	Collector Fluid	Antifreeze/water concentration in collector loop fluid is improper	Check fluid properties. Follow manufacturer's recommendations.
		Reverse thermosiphoning	Inspect check valve operation. Repair or replace.

Symptom	Source	Cause	Action
	Controls	Out of calibration	(See "Troubleshooting Controls")
Excessive vibration or noise in system	Pump	Cavitation	Check for air entry, check for resriction on pump suction side, clean strainer.
		Bearings	Check for hot or worn bearings. Check bearing alignment.
		Impeller	Inspect for misaligned shaft, repair, replace.
			Check balance of impeller. Clean, repair or replace.
	Piping	Entrapped air	Check automatic air vents. Vent manually. Force purge system, find and correct source of air entry.
		Supports	Check condition and adequacy of hangers. Repair hangers or install additional hangers.
Water hammer	Automatic valves	Open or close too fast	Install valves with slower action. Modify controls to slow valve action.

The following section of the diagnostic chart will be helpful if either the pump operating pressures or the system ΔT as defined in the operator's manual are out of the specified range

Symptom	Source	Cause	Action
Pump discharge pressure not in design range	If this condition is found carry out the following checks: 1. Check system static pressure and insure that it is in the proper range. 2. Using the pump inlet pressure and the pump discharge pressure, determine the pressure difference across the pump (ΔP).		
ΔP high		Generally the result of a flow restriction of some type	
	Valves	Flow control valves tampered with (closed)	Check seal on valves, if tampered with adjust flow as per commissioning procedure.
		Shut-off valves closed	Open.
		Automatic valves closed	Check controls, operation, and springs, repair or replace.
	Check valve	Jammed	Repair or replace.
	Air vents	Faulty -- causing air lock	Operate needle valve manually; check float control, inspect, clean, repair or replace.
	Collector	Passages clogged	Feel if some collectors hotter than others. Remove collector, backflush passages.
	Strainer	Flow restriction	Check and clean strainers.

Symptom	Source	Cause	Action
ΔP Low	Valves	Flow control valves tampered with (closed)	Check seal on valves, if tampered with, adjust flow as per commissioning procedure.
	Three-way valves	Internal leaking	Check and repair.
	Pump	Cavitating	Find source of air entry. Check for flow resriction on suction side, clean strainer.
		Mechanical failure	Check and repair.
ΔT low ΔP(s) normal	Collectors	Dirty	Clean surface.
		Insulation wet	Dry or replace insulation. Reseal collectors.
		Excessive condensation	Inspect seal, pipe gaskets, and weep holes. Repair.
	Pipe or tank insulation	Damaged, wet or missing	Repair or replace.
	Heat exchanger	Scaled up	Clean heat exchanger.
	Controls	Setting incorrect or drifting	Reset. (See "Troubleshooting Controls")
ΔT low ΔP(s) low	Flow control valves	Tampered with (opened)	Check seals on valves. If tampered with, adjust flow as per commissioning procedure.
	Three-way valves	Internal leaking	Repair.
	Controls	Incorrectly set	(See "Troubleshooting Controls")
ΔT high ΔP(s) normal	Controls	Incorrectly set	(See "Troubleshooting Controls")

Symptom	Source	Cause	Action
ΔT high $\Delta P(s)$ low	Pump	Cavitation	Find source of air entry, correct, clean strainer, check for restriction on suction side.
		Impeller damage	Check stagnation pressure. Repair.
	Three-way valves	Internal leak	Check and repair.
ΔT high ΔP high		Generally the result of a flow restriction of some type	
	Valves	Flow control valves tampered with (closed)	Check seal on valves. If tampered with, adjust flow as per commissioning procedure.
		Shut-off valves closed	Open.
		Automatic valves closed	Check controls, operation, and springs. Repair or replace.
	Check valve	Jammed	Repair or replace.
	Air vents	Faulty -- causing air lock	Operate needle valve manually; check float control, inspect, clean, repair or replace.
	Collector	Passages clogged	Feel if some collectors hotter than others. Remove collector, backflush passages.
	Strainer	Flow restriction	Check and clean strainers.
Pump run time too high			(See "Pump(s) running when no solar energy available")
Pump run time too low			Check ΔT and $\Delta P(s)$ and refer to appropriate section, if cause not evident, refer to "System Diagnostic Procedures".

TROUBLESHOOTING SOLAR CONTROLS

In troubleshooting solar controls, it is important to use a logical and systematic approach in isolating and correcting system faults. The following is the recommended procedure. This procedure is for variable resistance type controllers. For I.C. controllers, which use variable voltage sensors, voltages are measured instead of resistances.

Differential Controller Checks

1. Check power supply to controller.

2. Check that all components are wired correctly to controller (according to manufacturer's specifications).

3. If the pump or valve does not work in the "manual" mode, disconnect it from the controller and apply rated voltage to its input wires at the controller.

    a. If it runs, the pump is all right - the problem is in the control system.

    b. No operation - the pump or valve is faulty or the interconnecting wiring or relay is faulty. Isolate the fault and repair or replace the defective component.

4. Check all sensors for:

    - proper location,
    - secure attachment with no corrosion build-up,
    - proper wiring to controller.

5. Check each sensor for proper resistance by disconnecting it at the controller. If the measured resistances are as specified,

the fault is a controller problem. Proceed to Step 8. If the measured resistances do not correspond to the specification value for the temperature of the sensor location, then:

- the sensor is faulty,
- the interconnecting wiring is faulty.

6. Disconnect sensor from wiring leading to the controller. Check the sensors resistance at this point. If the resistance is not to specification, replace the sensor.

7. If sensor is accurate, check for corrosion at all wiring connections. Clean, reconnect and remeasure resistance at the controller. If the measured resistance is still not correct, replace the wiring between the sensor and the controller.

8. Controller operational check.

   - switch off the electrical power to all pumps and/or control valves and make sure the controller is set for the recommended temperature differential;

   - replace the temperature sensors at the collector and the tank with variable resistors (variable resistors with readouts will simplify the procedure). The resistors can be connected to the sensor terminals at the controller;

   - from the temperature sensor characteristic curve, determine the resistance associated with 5°C absolute temperature;

   - dial this resistance into the variable resistor on the output to the tank sensor. Record the resistance;

- with the controller set in the automatic position, gradually change the resistance on the collector side until an output is measured at the controller output terminals (to pump or control valve). Record the indicated resistance;

- vary the resistance until there is no longer an output at the controller output terminals. Record the indicated resistance;

- reset the tank variable resistor for the resistance associated with a 15°C absolute temperature;

- repeat the above procedure determining the collector resistance to receive an output at the output terminal and the resistance to receive no output. Record both resistances;

- calculate the differential resistance, and from the temperature sensor characteristic curve determine the temperature differential;

- compare this with the original setting of differential temperature;

- if the two figures disagree substantially (more than ten percent), adjust the controller setting and repeat the above test.

9. Sensor Calibration Check

Preparation

1. Obtain a copy of the temperature sensor characteristic curve from the appropriate manufacturer (resistance vs. temperature).

2. Obtain a digital multimeter with an appropriate probe to determine as accurately as possible the temperature at the point the sensor is intended to sense.

Method

Determine the temperatures at the points the sensor is intended to sense. These will likely be the absorber plate in one of the collectors and the temperature in the lower third of the storage tank.

Measure with an ohm meter the resistance shown by the sensor. This should be done at two temperatures for each sensor, for example:

For collector sensors:

1. Cool Temperature - as early as possible in the morning, preferably on a cloudy day.

2. Hot Temperature - mid to late afternoon on a sunny day.

For storage tank sensors:

1. Cool Temperature - after a major draw of heat from storage to load on a cloudy day and before the auxiliary heat has replenished the draw (where applicable).

2. Hot Temperature - late on a sunny day before a major draw of heat or on a day when the load is reduced.

Compare the measured resistance with that shown on the manufacturer's table or graph for the appropriate temperature.

If the resistance varies from the expected value, the sensor or sensor lead connections may be corroded or the sensor may have been damaged by heat extremes. Check both and replace as necessary then repeat the test.

High Temperature Limit Protection

High temperature limit switches are used in solar systems either to protect collectors, storage tanks or as a secondary safeguard against failure of the mixing valve on the outlet to load.

Control logic should be set up so that the temperature limit switch will not inhibit the initial start up of the collector loop pump, but will activate if, after a reasonable length of time, the collector temperature has not fallen.

For closed loop glycol systems, the high temperature limit or control logic may be used to divert flow to a heat purge coil.

High Temperature Protection for Storage Tanks

High temperature limit switches are used to protect storage tanks from over temperature conditions. In some cases, a tank temperature limit can serve as a secondary protection against scalding temperatures being delivered to load if the mixing valve fails.

High Temperature Limit Switch Checkout

The checkout procedure is similar to that for freeze protection. The switch or sensor is immersed in hot water, which is heated until the device activates and then cooled until it reverses. The temperatures and resistances for these points are recorded and checked against the specifications.

GENERAL SYSTEM DIAGNOSTIC PROCEDURE

The performance of a solar system depends on the interaction of all system components, outside conditions, and the load imposed on the system.

There are cases in which a general decrease in the performance of a system is indicated by a decrease in system operating time, temperature differences, measured energy collected, or by an increase in the required auxiliary energy. In some cases, the particular problem cannot be isolated by the operator. The following is a general diagnostic procedure which can, in most cases, isolate the causes.

Carrying out this procedure requires some knowledge of solar systems and a number of portable instruments; therefore, a troubleshooting technician or engineer may be required.

1. The first step is a visual inspection of the system paying special attention to such items as completeness and condition of insulation and whether the collectors are clean and free of new shading.

2. Verifying flow rates.

   The operating flow rates in each loop should be checked by the means provided. This may be by using pump differential pressures or by reading a flow meter if one is installed in the particular loop. (See commissioning procedure.)

3. If the flow rate in any loop in the system is lower than specified, the flow restriction can be isolated by checking the pressures at the monitoring points provided in the system and comparing these with the commissioned values.

4. If the flow rates in all points of all loops are as specified, check the fluid temperatures at each monitoring point on a clear sunny day.

5. Verify the flow balance through the collector banks.

   The face temperature of each collector should be checked by feel or, preferably, with a pyrometer. Collectors that are significantly warmer or cooler than their neighbours indicates flow blockages and stagnation or high flows respectively.

   It is a good idea to check the bank temperature balance by the method shown in the commissioning procedure.

6. Verify the effectiveness of the heat exchanger as in the commissioning procedure. A reduced effectiveness could indicate scaling of the heat exchanger surfaces.

7. Perform the preliminary thermal performance test as shown in the commissioning procedure and compare the efficiency with the commissioned values. This will detect degradation of the collectors' performance.

8. Check the calibration of the control system as described in "Troubleshooting Solar Controls."

If satisfied that the operating characteristics of the system are normal, investigate the non-operating features.

9. Isolate the system from load and bring the storage temperatures up during the day. Read the storage temperature at nightfall and shut off the system. Check the storage temperature in the morning. If the storage temperature has dropped significantly, suspect damaged or wet insulation, or reverse thermosyphoning (usually the result of a faulty check valve).

PERFORMANCE MONITORING

ACE ATHLETIC ASSOCIATION
CLOSED LOOP SYSTEM - DOMESTIC HOT WATER
CAFETERIA AND RECREATION CENTRE

Two meters are required to determine the overall performance of the solar heating system. One will measure the total energy used in heating the water. The second will measure the input of the auxiliary heater. From these two measurements, the input of the solar system can be calculated.

The meter selected to measure the total energy is:

SIEMENS Calorimetric Counter (Heat Integrating Unit)
Model: M72131-A124-A2
available from:
  Alpha Controls and Instrumentation
  160 Gibson Drive, Unit 7
  Markham, Ontario
  (416) 499-1672

This meter requires inputs from a pulse output flow meter and two platinum RTD's. The flow meter is:

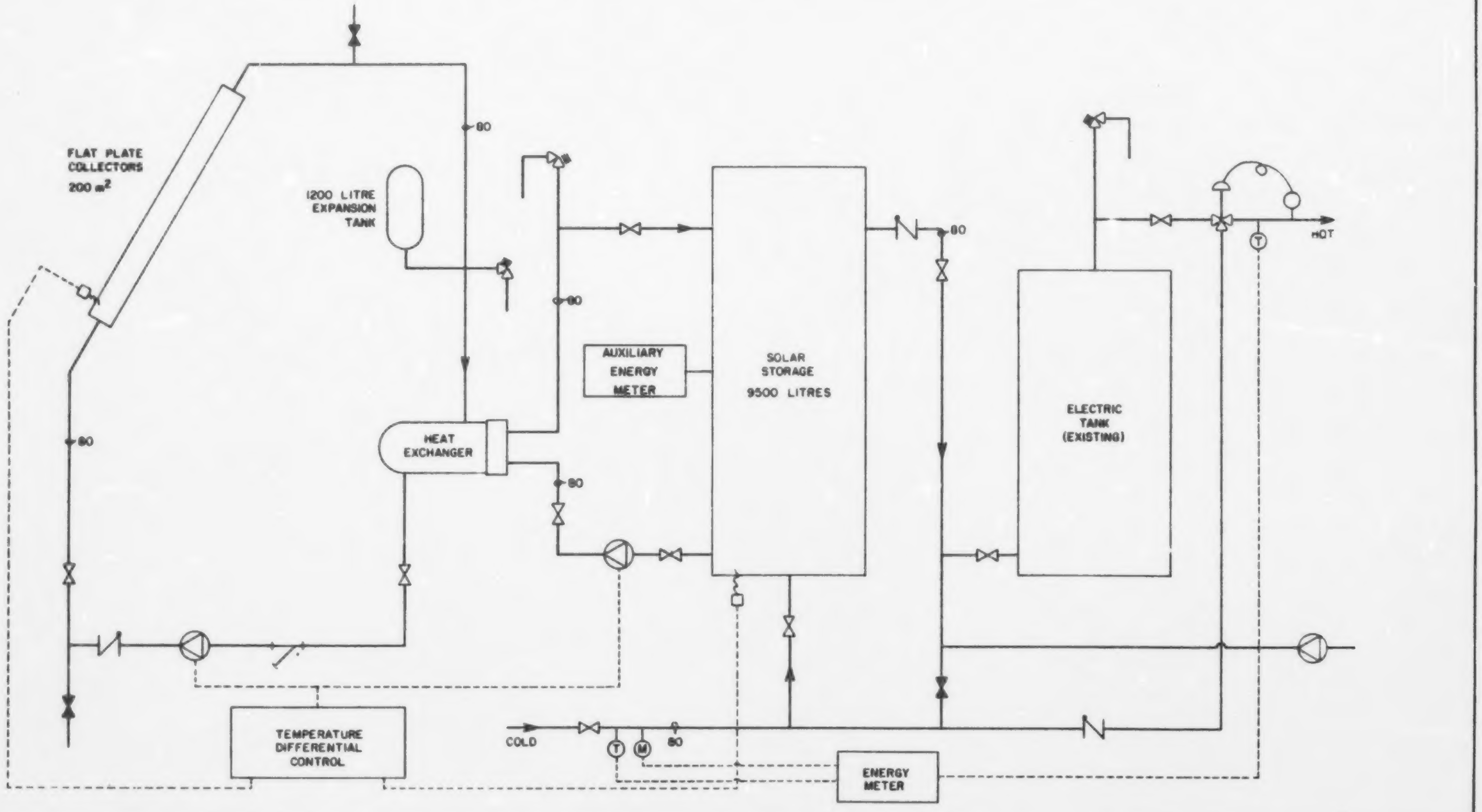
NEPTUNE Flow Meter
  3 inch Green Seal Crest Meter
    - with model 157 register
    - with model 34 impulse switch 100 litres per pulse
available from:
  Neptune Meters Limited
  3526 Lakeshore Blvd West
  Toronto, Ontario
  M8W 1N7
  (416) 259-4211

The required RTD's are:

HERAEUS Resistence Thermometers (two required)
Model: WGN9 1 Pt 100 to DIN 43 760
available from:
Alpha Controls and Instrumentation
160 Gibson Drive, Unit 7
Markham, Ontario
(416) 499-1672

A standard Sangamo kilowatt-hour meter will be used to measure the input of the auxiliary heater.

Note the figure illustrating the arrangement of the performance monitoring equipment. A sample form in which this performance data will be recorded each month is attached.


FLAT PLATE COLLECTORS 200 m²
1200 LITRE EXPANSION TANK
80
80
80
80
80
80
HEAT EXCHANGER
AUXILIARY ENERGY METER
SOLAR STORAGE 9500 LITRES
ELECTRIC TANK (EXISTING)
HOT
COLD
T
M
T
TEMPERATURE DIFFERENTIAL CONTROL
ENERGY METER

LEGEND

Ⓣ TEMPERATURE PROBE

Ⓜ FLOW METER

DATE	AUG 1982	
DESIGNED	S.B.	
DRAWN	C.H.	
CHECKED	J.R.	

ACME ASSOCIATES
Engineers/Ingénieurs

ACE ATHLETIC ASSOCIATION

Solar Water Heating Facility --A

Schematic with Performance Monitoring Equip.

SCALE	PROJECT NO.	DWG. NO.	REV.
N T S	1458-81	5	

"SYSTEM A"

MONITORING MONTHLY REPORT

PROJECT NAME: Ace Athletic Association

PROJECT NUMBER: 123456739

DATE:

Please fill in energy quantities indicated below:

AUXILIARY ENERGY INPUT (meter number)

TOTAL ENERGY INPUT (meter number)

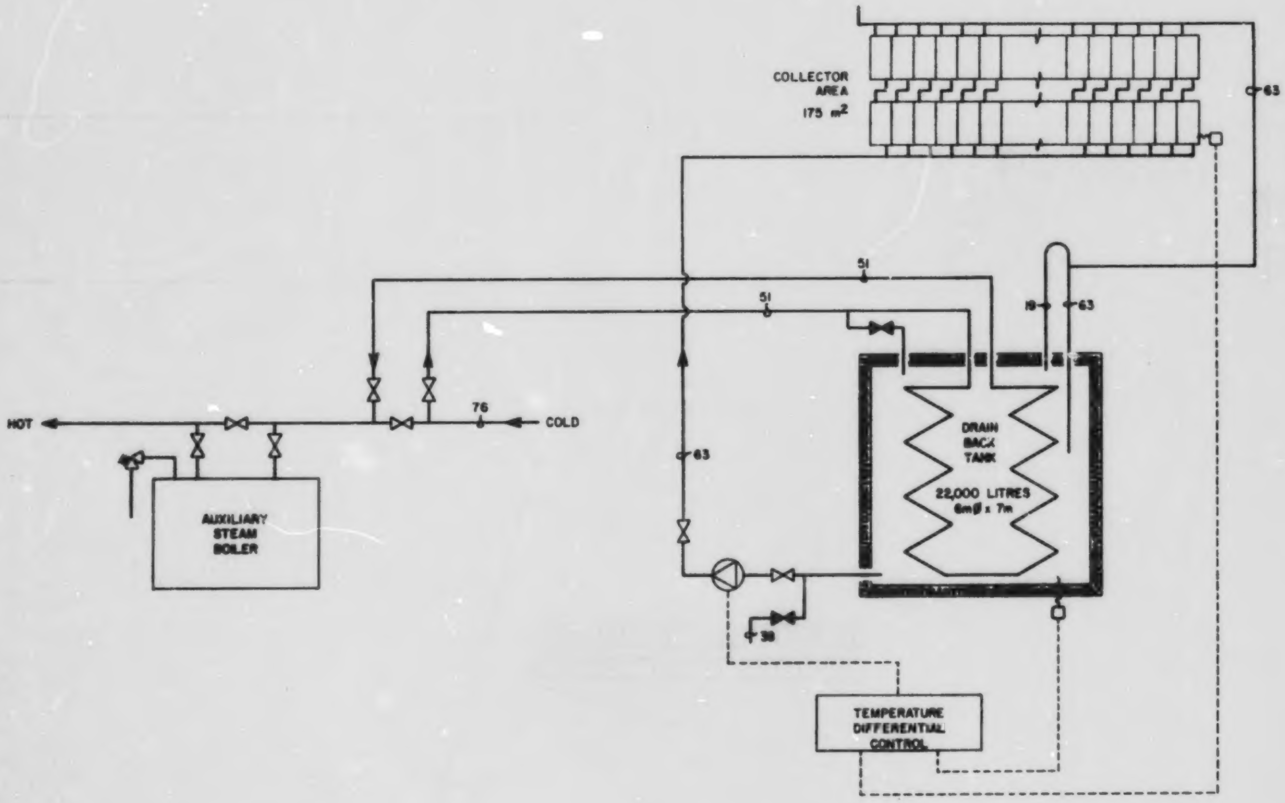
RECORD OF SYSTEM PROBLEMS:
(Briefly explain any system problems encountered)

EXAMPLE SYSTEM "B"

E.G. INDUSTRIES
Solar Process Water Heating System

This system is a simple domestic hot water or process hot water heating system with a drainback water collection loop.

The auxiliary heating system consists of a steam heated boiler.

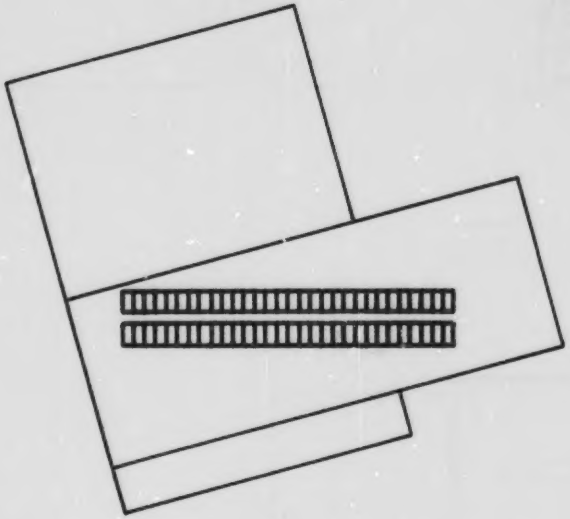


DATE
JUNE, 1982
DESIGNED S.B.
DRAWN C.H.
CHECKED J.R.

ACME ASSOCIATES
Engineers/Ingénieurs

E.G. INDUSTRIES
Solar Process Water Heating System
Schematic
SCALE N.T.S.
PROJECT NO 1443-81
DWG. NO 1
REV

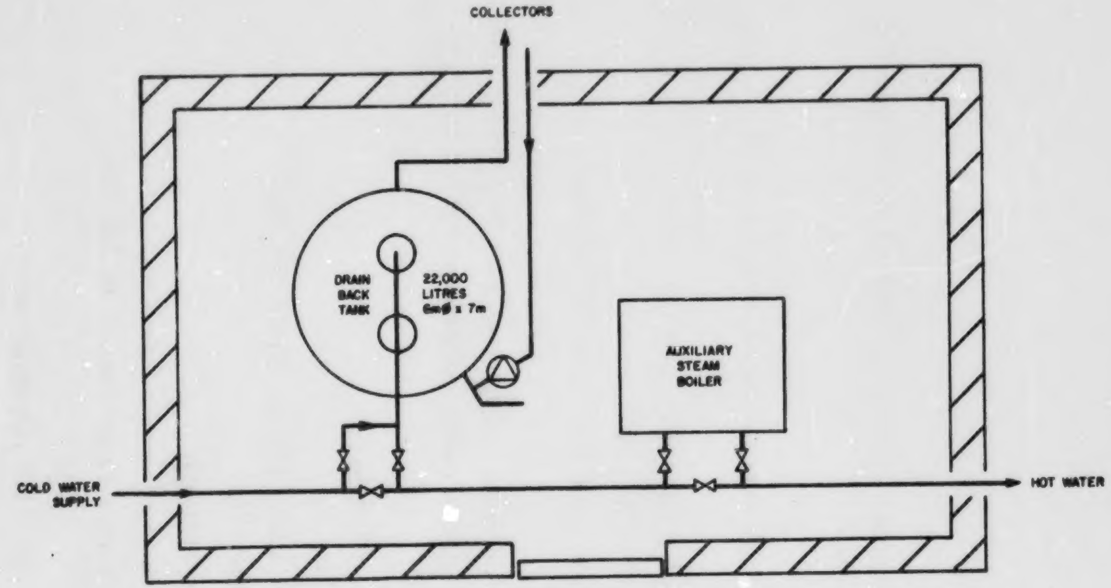
"SYSTEM B"



NOTE: COLLECTOR AREA 175 m^2

DATE JUNE, 1982		E.G. INDUSTRIES	
DESIGNED	S.B.	Solar Process Water Heating System	
DRAWN	J.R.		
CHECKED	C.H.	COLLECTOR LAYOUT	
ACME ASSOCIATES Engineers/Ingénieurs		SCALE N.T.S	PROJECT NO 1443-81 · DWG. NO 2 · REV

"SYSTEM B"



DATE JUNE, 1982
DESIGNED S.B.
DRAWN J.R.
CHECKED C.H.

ACME ASSOCIATES
Engineers/Ingénieurs

E.G. INDUSTRIES
Solar Process Water Heating System
EQUIPMENT ROOM

SCALE	PROJECT NO	DWG. NO	REV
N.T.S.	1443-81	3	

"SYSTEM B"

SELECTED INSTRUMENTATION

E.G. INDUSTRIES
DRAINBACK SYSTEM - SOLAR PROCESS HOT WATER

1. Seven Peterson Plugs, part number 110, to be installed in the specified locations in elbows.

2. Four Platinum RTD (DIN 43760), Omega Engineering Model PR-12 wire wound probes with accuracy of;
   plus or minus .3° C @ 0°C
   and plus or minus .6° C @ 100°C
   to be installed in temperature wells located in 90° elbows.

3. Digital temperature readouts; Omega Engineering Part No. 44030; Five Point selector switch, four wire lead-resistance compensated standard platinum RTD (DIN 43760) with,
   range from 0°C - 100°C,
   resolution of .1°C,
   accuracy .1% of scale; plus or minus one digit,
   stability - 100 ppm/°C
   sampling time - 1 second.

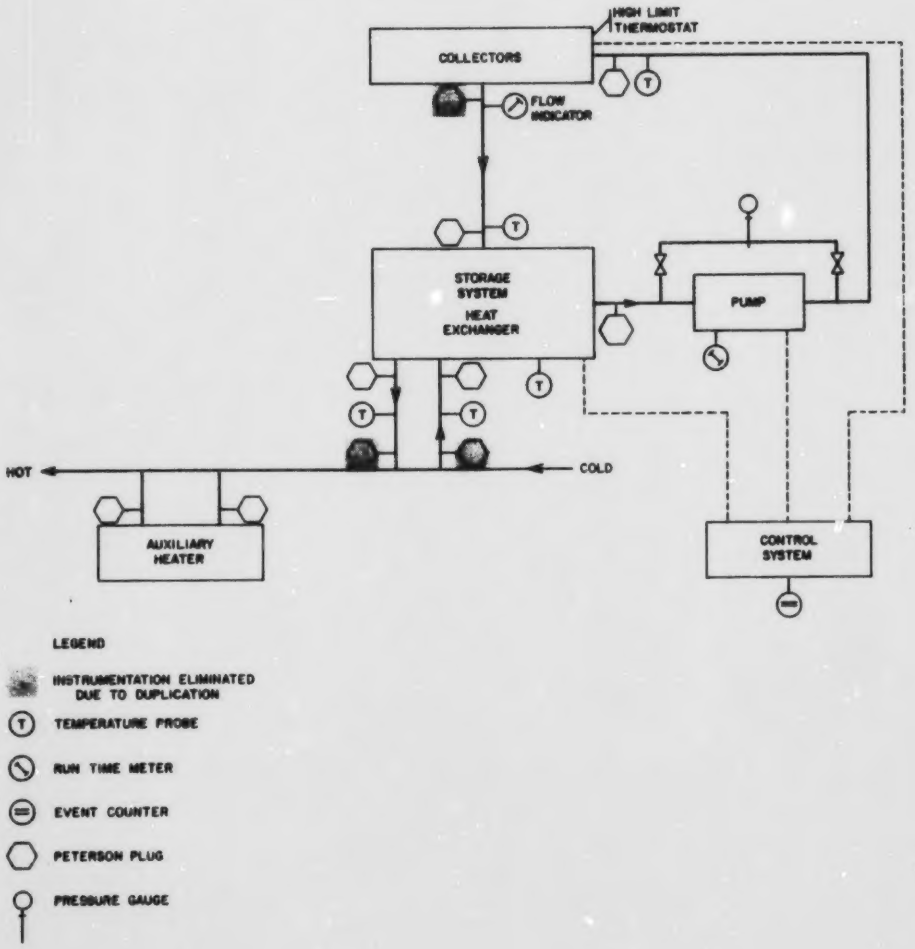
4. One Trerice pressure gauge with a range from 0 to 500 kPa.

5. One Bach Simpson Number 1357 ETIF run-time meter.

6. One Hecom AO-040 event counter.

7. One Migginson flow indicator.

8. One high limit thermostat.



SYSTEM B
E.G. Industries Drain Back
Solar Process Hot Water System
(Modular Representation with Instrumentation)

START-UP PROCEDURES

E.G. INDUSTRIES
DRAINBACK SYSTEM - SOLAR PROCESS HOT WATER

INDEX

1. General Introduction to Start-Up Document

2. Site Inspection
    - Preparations
    - Collectors
    - Piping
    - Insulation
    - Thermal Storage
    - Electrical

3. Differential Controller Tests
    - Preparations
    - Responsibilities
    - Scheduling
    - Test No. 1 - Fail Safe Operation
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    - Test No. 3 - Drainback Test

4. Motor and Pump Test
    - Preparations - Motor
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    - Responsibilities
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    - Direction of Rotation
    - Motor - Amperage
    - Pump - Circulation Test

5. Leak Test

6. Final Visual Inspection

7. Flow Balancing
    - Preliminary Information
    - Collector Loop Flow Rate

1. General Introduction to Start-Up Document

Start-up is a series of tests and inspections performed during and immediately after construction to ensure that the system and its components are installed correctly, and are capable of operating at specified levels.

The following tests are performed during and immediately following the construction phase of the project. Since component testing does not require the system to be in a completed and operational mode, the component tests may be done immediately following the installation of the component. In cases where various pre-conditions must be met in order to perform the test, testing should be done at the earliest possible date following the installation of these components. When the system has been fully constructed, a final visual inspection and system flow checks should be performed.

Supportive documentation must be prepared following each test or series of tests. This documentation will be maintained in a project file and summarized when the testing is complete. This documentation will help the owner in his final assessment of the system.

Testing may be done whenever components are made available for testing. It is not necessary to test them in the order the tests are described.

2. Site Inspection

Preparations

- obtain a copy of the design specifications, design drawings and shop drawings;

- obtain copies of the manufacturer's specifications for all major components in the system (collectors, pumps, heat exchangers, controllers, control valves);

- prepare an "inspection" checklist. This should be a specification sheet that details the components that should be installed. This sheet will be updated and dated following each inspection;

- the contractor should attach a sticker to pump timers indicating:

    - the date the system became fully operational,
    - the pump timer reading on that date.

Collectors

- verify that the number and type of collectors specified in the shop drawings have been installed;

- verify that the collectors have been installed in accordance with the designer's and manufacturer's recommendations;

- verify that the collectors are fed from the bottom and returned from the top;

- ensure that adequate play is available for both full expansion and full contraction;

- check the security of all fasteners including those holding the collectors to the support structure, and those used in assembly of the support structure;

- ensure that load spreading washers have been used where necessary on collector attachment points;

- verify that flashings are firmly supported;

- ensure that there is a isolating gasket between any aluminum collectors and a steel frame.

Piping

- verify that all pipes, valves and fittings have been installed as specified;

- ensure that gate valves are used only for fully open or fully closed applications;

- verify that the pump is physically connected in the proper flow direction;

- verify that pumps have an adequate suction head. The pump must be below the water level in the tank on start-up;

- verify that the heat exchanger connections are made in the proper direction;

- verify that all pipes to and from the collectors are sloped 1 in 48, or better; (Note: Be sure this slope is maintained on the vertical plane when pipes are traversing sloped sections and/or elbowed sections.)

- verify that the pump speed is set at the setting recommended by the manufacturer;

- verify that there are sufficient pipe hangers, supports and expansion devices to compensate for thermal effects.

Insulation

- verify that the levels of insulation are as specified;
- verify that all insulation is:
    - securely fastened,
    - appropriately weatherproofed and protected from physical abuse,
    - protected from ultra-violet degradation (if applicable).
- verify that all test points are properly insulated;
- verify that any seams on piping jackets point downward to prevent moisture penetration;
- verify that there is insulation on the underside of storage tanks;
- verify that insulation does not impede the proper cooling of motors.

Thermal Storage

- verify that the storage tank is as specified or designed;
- verify that the pressure relief valves are installed and set to protect the system component with the lowest pressure rating;
- if a non-toxic fluid is specified, verify that a label is affixed in the vicinity of the fill valve, indicating that only non-toxic fluid be used.

Electrical

- verify that temperature sensors are firmly supported and protected from physical damage;
- ensure that all sensor wiring is protected from physical damage;
- verify that controls are located such that accidental adjustment is not possible;
- verify that wiring is installed according to local electrical codes;
- ensure that the instrumentation required for commissioning is available and properly installed.

3. Control System Tests

Preparations

- obtain a copy of the temperature sensor characteristic curve from the manufacturer (resistance vs. temperature);
- obtain variable resistors which can be substituted for the system temperature sensors. These resistors can either have a built-in means of reading the set resistance or can be standard potentiometers from which the resistance can be determined using an accurate resistance meter. The variable resistors should have a range of 0 to 100,000 ohms;
- the controller should be wired for power.

Responsibilities

- the tests shall be the responsibility of the contractor;
- all testing will be witnessed by the owner or by his appointed representative and the design consultant.

Scheduling

- the tests will be performed following the installation of the controller and temperature sensors;
- the tests may be conducted at any level of solar insolation and system flow.

Test No. 1 - Fail Safe Operation

- switch off the electrical power to all pumps and/or control valves;
- verify that the controller is receiving electrical power;

- test the controller for short circuit protection (zero resistance). With a test light on the leads to the pump or to the control valve it operates, short circuit the temperature sensor leads. The test light should not come on;

- test the controller for open circuit protection (infinite resistance). With a test light on the leads to the pump it operates, open circuit the temperature sensor leads. The test light should not come on.

Test No. 2 - Differential Setting

- switch off the electrical power to pumps and/or control valves;

- set the differential controller for the recommended temperature differential;

Specified temperature differential on _8_ °C
off _2_ °C

- follow the specified procedure and record the readings in the chart on the following page;

- disconnect collector and tank sensors at the controller and substitute with appropriate variable resistors. The resistors can be connected to the sensor terminals at the controller;

- from the temperature sensor characteristic curve, determine the resistance associated with 5°C absolute temperature;

- dial this resistance into the variable resistor on the output to the tank sensor. Record the resistance;

- with the controller set in the automatic position, gradually change the resistance on the collector variable resistor until an output is measured at the controller output terminals (to pump). Record the indicated resistance;

- vary the resistance until there is no longer an output at the controller output terminals. Record the indicated resistance;

- calculate the differential resistance and, from the temperature sensor characteristic curve, determine the temperature differential;

- compare this with the original setting of differential temperature using the following equation:

$$\frac{100\% \times \text{differential temperature setting} - \text{differential temperature}}{\text{differential temperature setting}} = \underline{\qquad}\%$$

- reset the tank variable resistor for the resistance associated with a 15°C absolute temperature and repeat the above procedure.

Tank Sensor = 5°C

Tank Sensor	Collector Sensor	Differential	Temperature Differential	% Temperature Difference
_____ohms	on: _____ohms	_____ohms	_______°C	_________
	off: _____ohms	_____ohms	_______°C	_________

Tank Sensor = 15°C

Tank Sensor	Collector Sensor	Differential	Temperature Differential	% Temperature Difference
_____ohms	on: _____ohms	_____ohms	_______°C	_________
_____ohms	off: _____ohms	_____ohms	_______°C	_________

- if the percent temperature difference is substantial (more than ten percent), for any of the four tests, adjust the controller setting and repeat the above test.

Thermistor Resistance versus Temperature

PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032	PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032
Ω@25°C	2252	3000	5000	10.000	30.000	Ω@25°C	2252	3000	5000	10.000	30.000
BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE
END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED	END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED
TEMP. °C	RESISTANCE Ω					TEMP. °C			RESISTANCE Ω		
—80	1660K	2211K	3685K	3558K		—20	21.87K	29.13K	48.56K	78.91K	271.2K
79	1518K	2022K	3371K	3296K		19	20.64K	27.49K	45.83K	74.91K	256.5K
78	1390K	1851K	3086K	3055K		18	19.48K	25.95K	43.27K	71.13K	242.8K
77	1273K	1696K	2827K	2833K		17	18.40K	24.51K	40.86K	67.57K	229.8K
76	1167K	1555K	2592K	2629K		16	17.39K	23.16K	38.61K	64.20K	217.6K
75	1071K	1426K	2378K	2440K		15	16.43K	21.89K	36.49K	61.02K	206.2K
74	982.8K	1309K	2182K	2266K		14	15.54K	20.70K	34.50K	58.01K	195.4K
73	902.7K	1202K	2005K	2106K		13	14.70K	19.58K	32.63K	55.17K	185.2K
72	829.7K	1105K	1843K	1957K		12	13.91K	18.52K	30.88K	52.48K	175.6K
71	763.1K	1016K	1695K	1821K		11	13.16K	17.53K	29.23K	49.94K	166.6K
—70	702.3K	935.4K	1560K	1694K		—10	12.46K	16.60K	27.67K	47.54K	158.0K
69	546.7K	861.4K	1436K	1577K		9	11.81K	15.72K	26.21K	45.27K	150.0K
68	595.9K	793.7K	1323K	1469K		8	11.19K	14.90K	24.83K	43.11K	142.4K
67	549.4K	731.8K	1220K	1369K		7	10.60K	14.12K	23.54K	41.07K	135.2K
66	506.9K	675.2K	1126K	1276K		6	10.05K	13.39K	22.32K	39.14K	128.5K
65	467.9K	623.3K	1039K	1190K		5	9534	12.70K	21.17K	37.31K	122.1K
64	432.2K	575.7K	959.9K	1111K		4	9046	12.05K	20.08K	35.57K	116.0K
63	399.5K	532.1K	887.2K	1037K		3	8586	11.44K	19.06K	33.93K	110.3K
62	369.4K	492.1K	820.5K	968.4K		2	8151	10.86K	18.10K	32.37K	104.9K
61	341.8K	455.3K	759.2K	904.9K		— 1	7741	10.31K	17.19K	30.89K	99.80K
—60	316.5K	421.5K	702.9K	845.9K		0	7355	9796	16.33K	29.49K	94.98K
59	293.2K	390.5K	651.1K	791.1K		+ 1	6989	9310	15.52K	28.15K	90.41K
58	271.7K	361.9K	603.5K	740.2K		2	6644	8851	14.75K	26.89K	86.09K
57	252.0K	335.7K	559.7K	692.8K		3	6319	8417	14.03K	25.69K	81.99K
56	233.8K	311.5K	519.4K	648.8K		4	6011	8006	13.34K	24.55K	78.11K
55	217.1K	289.2K	482.2K	607.8K		5	5719	7618	12.70K	23.46K	74.44K
54	201.7K	268.6K	447.9K	569.6K		6	5444	7252	12.09K	22.43K	70.96K
53	187.4K	249.7K	416.3K	534.1K		7	5183	6905	11.51K	21.45K	67.66K
52	174.3K	232.2K	387.1K	501.0K		8	4937	6576	10.96K	20.52K	64.53K
51	162.2K	216.0K	360.2K	470.1K		9	4703	6265	10.44K	19.63K	61.56K
—50	151.0K	201.1K	335.3K	441.3K		+10	4482	5971	9951	18.79K	58.75K
49	140.6K	187.3K	312.3K	414.5K		11	4273	5692	9486	17.98K	56.07K
48	131.0K	174.5K	291.0K	389.4K		12	4074	5427	9046	17.22K	53.54K
47	122.1K	162.7K	271.3K	366.0K		13	3886	5177	8628	16.49K	51.13K
46	113.9K	151.7K	253.0K	344.1K		14	3708	4939	8232	15.79K	48.84K
45	106.3K	141.6K	236.2K	323.7K		15	3539	4714	7857	15.13K	46.67K
44	99.26K	132.2K	220.5K	304.6K		16	3378	4500	7500	14.50K	44.60K
43	92.72K	123.5K	205.9K	286.7K		17	3226	4297	7162	13.90K	42.64K
42	86.65K	115.4K	192.5K	270.0K		18	3081	4105	6841	13.33K	40.77K
41	81.02K	107.9K	180.0K	254.4K		19	2944	3922	6536	12.79K	38.99K
—40	75.79K	101.0K	168.3K	239.8K	884.6K	+20	2814	3748	6247	12.26K	37.30K
39	70.93K	94.48K	157.5K	226.0K	830.9K	21	2690	3583	5972	11.77K	35.70K
38	66.41K	88.46K	147.5K	213.2K	780.8K	22	2572	3426	5710	11.29K	34.17K
37	62.21K	82.87K	138.2K	201.1K	733.9K	23	2460	3277	5462	10.84K	32.71K
36	58.30K	77.66K	129.5K	189.8K	690.2K	24	2354	3135	5225	10.41K	31.32K
35	54.66K	72.81K	121.4K	179.2K	649.3K	25	2252	3000	5000	10.00K	30.00K
34	51.27K	68.30K	113.9K	169.3K	611.0K	26	2156	2872	4787	9605	28.74K
33	48.11K	64.09K	106.9K	160.0K	575.2K	27	2064	2750	4583	9227	27.54K
32	45.17K	60.17K	100.3K	151.2K	541.7K	28	1977	2633	4389	8867	26.40K
31	42.42K	56.51K	94.22K	143.0K	510.4K	29	1894	2523	4204	8523	25.31K
—30	39.86K	53.10K	88.53K	135.2K	481.0K	+30	1815	2417	4029	8194	24.27K
29	37.47K	49.91K	83.22K	127.9K	453.5K	31	1739	2317	3861	7880	23.28K
28	35.24K	46.94K	78.26K	121.1K	427.7K	32	1667	2221	3702	7579	22.33K
27	33.15K	44.16K	73.62K	114.6K	403.5K	33	1599	2130	3549	7291	21.43K
26	31.20K	41.56K	69.29K	108.6K	380.9K	34	1533	2042	3404	7016	20.57K
25	29.38K	39.13K	65.24K	102.9K	359.6K	35	1471	1959	3266	6752	19.74K
24	27.67K	36.86K	61.45K	97.49K	339.6K	36	1412	1880	3134	6500	18.96K
23	26.07K	34.73K	57.90K	92.43K	320.9K	37	1355	1805	3008	6258	18.21K
22	24.56K	32.74K	54.58K	87.66K	303.3K	38	1301	1733	2888	6026	17.48K
21	23.18K	30.87K	51.47K	83.16K	286.7K	+39	1249	1664	2773	5805	16.80K

Thermistor Resistance Versus Temperature

PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032
Ω @25°C	2252	3000	5000	10,000	30,000
BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE
END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED
TEMP. °C	RESISTANCE Ω				
+40	1200	1598	2663	5592	16.15K
41	1152	1535	2559	5389	15.52K
42	1107	1475	2459	5193	14.92K
43	1064	1418	2363	5006	14.35K
44	1023	1363	2272	4827	13.80K
45	983.8	1310	2184	4655	13.28K
46	946.2	1260	2101	4489	12.77K
47	910.2	1212	2021	4331	12.29K
48	875.8	1167	1944	4179	11.83K
49	842.8	1123	1871	4033	11.39K
+50	811.3	1081	1801	3893	10.97K
51	781.1	1040	1734	3758	10.57K
52	752.2	1002	1670	3629	10.18K
53	724.5	965.0	1608	3504	9807
54	697.9	929.6	1549	3385	9450
55	572.5	895.8	1493	3270	9109
56	648.1	863.3	1439	3160	8781
57	624.8	832.2	1387	3054	8467
58	602.4	802.3	1337	2952	8166
59	580.9	773.7	1290	2854	7876
+60	560.3	746.3	1244	2760	7599
61	540.5	719.9	1200	2669	7332
62	521.5	694.7	1158	2582	7076
63	503.3	670.4	1117	2497	6830
64	485.8	647.1	1079	2417	6594
65	469.0	624.7	1041	2339	6367
66	452.9	603.3	1006	2264	6149
67	437.4	582.6	971.1	2191	5940
68	422.5	562.8	938.0	2122	5738
69	408.2	543.7	906.3	2055	5545
+70	394.5	525.4	875.7	1990	5359
71	381.2	507.8	846.4	1928	5180
72	368.5	490.9	818.3	1868	5007
73	356.2	474.7	791.2	1810	4842
74	344.5	459.0	765.1	1754	4682
75	333.1	444.0	740.0	1700	4529
76	322.3	429.5	715.9	1648	4381
77	311.8	415.6	692.7	1598	4239
78	301.7	402.2	670.3	1549	4102
79	292.0	389.3	648.8	1503	3970
+80	282.7	376.9	628.1	1458	3843
81	273.7	364.9	608.2	1414	3720
82	265.0	353.4	588.9	1372	3602
83	256.7	342.2	570.4	1332	3489
84	248.6	331.5	552.6	1293	3379
85	240.9	321.2	535.4	1255	3273
86	233.4	311.3	518.8	1218	3172
87	226.2	301.7	502.8	1183	3073
88	219.3	292.4	487.4	1149	2979
89	212.6	283.5	472.6	1116	2887
+90	206.1	274.9	458.2	1084	2799
91	199.9	266.6	444.4	1053	2714
92	193.9	258.6	431.0	1023	2632
93	188.1	250.9	418.2	994.2	2552
94	182.5	243.4	405.7	966.3	2476
95	177.1	236.2	393.7	939.3	2402
96	171.9	229.3	382.1	913.2	2331
97	166.9	222.6	370.9	887.9	2262
98	162.0	216.1	360.1	863.4	2195
99	157.3	209.8	349.7	839.7	2131

PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032
Ω @25°C	2252	3000	5000	10,000	30,000
BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE
END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED
TEMP. °C			RESISTANCE Ω		
+100	152.8	203.8	339.6	816.8	2069
101	148.4	197.9	329.8	794.6	2009
102	144.2	192.2	320.4	773.1	1950
103	140.1	186.8	311.3	752.3	1894
104	136.1	181.5	302.5	732.1	1840
105	132.3	176.4	294.0	712.6	1788
106	128.6	171.4	285.7	693.6	1737
107	125.0	166.7	277.8	675.3	1688
108	121.6	162.0	270.1	657.5	1640
109	118.2	157.6	262.6	640.3	1594
+110	115.0	153.2	255.4	623.5	1550
111	111.8	149.0	248.4	607.3	1507
112	108.8	145.0	241.6	591.6	1465
113	105.8	141.1	235.1	576.4	1425
114	103.0	137.2	228.7	561.6	1386
115	100.2	133.6	222.6	547.3	1348
116	97.6	130.0	216.7	533.4	1311
117	95.0	126.5	210.9	519.9	1276
118	92.5	123.2	205.3	506.8	1241
119	90.0	119.9	199.9	494.1	1208
+120	87.7	116.8	194.7	481.6	1176
121	85.4	113.8	189.6	469.8	1145
122	83.2	110.8	184.7	458.2	1114
123	71.1	107.9	179.9	446.9	1085
124	79.0	105.2	175.3	435.9	1057
125	77.0	102.5	170.8	425.3	1029
126	75.0	99.9	166.4	414.9	1002
127	73.1	97.3	162.2	404.9	976.3
128	71.3	94.9	158.1	395.1	951.1
129	69.5	92.5	154.1	385.6	926.7
+130	67.8	90.2	150.3	376.4	903.0
131	66.1	87.9	146.5	367.4	880.0
132	64.4	85.7	142.9	358.7	857.7
133	62.9	83.6	139.4	350.3	836.1
134	61.3	81.6	136.0	342.0	815.0
135	59.8	79.6	132.6	334.0	794.6
136	58.4	77.6	129.4	326.3	774.8
137	57.0	75.8	126.3	318.7	755.6
138	55.6	73.9	123.2	311.3	736.9
139	54.3	72.2	120.3	304.2	718.8
+140	53.0	70.4	117.4	297.2	701.2
141	51.7	68.8	114.6	290.4	684.1
142	50.5	67.1	111.9	283.8	667.5
143	49.3	65.5	109.2	277.4	651.3
144	48.2	64.0	106.7	271.2	635.6
145	47.0	62.5	104.2	265.1	620.3
146	45.9	61.1	101.8	259.2	605.5
147	44.9	59.6	99.40	253.4	591.1
148	43.8	58.3	97.10	247.8	577.1
149	42.8	56.9	94.87	242.3	563.5
+150	41.9	55.6	92.70	237.0	550.2

Note: Data in black refer to thermistors with ±0.2°C interchangeability.
Data in blue refer to thermistors with ±0.1°C interchangeability.
Temperature/resistance figures are the same for both types.

Note: Only thermistors with ±0.2°C interchangeability are available encased in Teflon as standard parts. For Part No. of Teflon encased thermistors add 100 to part No. of ±0.2°C interchangeable thermistors. Example: 44005 is a standard thermistor, 44105 is a Teflon encased thermistor with the same resistance values.

Test No. 3 - Drainback Test

- a drainback test shall be performed on all systems using a drainback operation for freeze protection;

- note the level of the heat transfer fluid in the solar storage tank site glass with the collector loop fully drained;

  Level (with respect to marked line) __________ cm

- circulate the heat transfer fluid through the collectors for a minimum of fifteen minutes to ensure that all collectors are fully wetted;

- switch off electrical power to the collector loop pump. This can be attained by switching the controller to the "off" position;

- measure and record the time required for the heat transfer fluid to drainback to the solar storage tank;

  Time for drainback __________ min

- the drainback time interval will begin when the pump is shut off and will terminate when the heat transfer fluid is restored to its original level in the solar storage tank site glass;

- complete drainback of the heat transfer fluid should occur in five minutes or less.

4. Motor and Pump Test

Preparations - Motor

- all three phase motors should be checked for proper direction of rotation;

- verify that the motor is fully wired, protected, and ready to operate.

Preparations - Pump

- a time delay device should be attached to three phase pumps used in drainback systems. The time delay switch should prevent power being applied to the pump for an interval of at least the observed drainback time. This is to prevent damage that can occur to a three phase motor, if it is started up while running backwards;

- assure that all valves are in the position required for normal system operation;

- collect the applicable pump curves.

Responsibilities

- the test shall be the responsibility of the contractor;

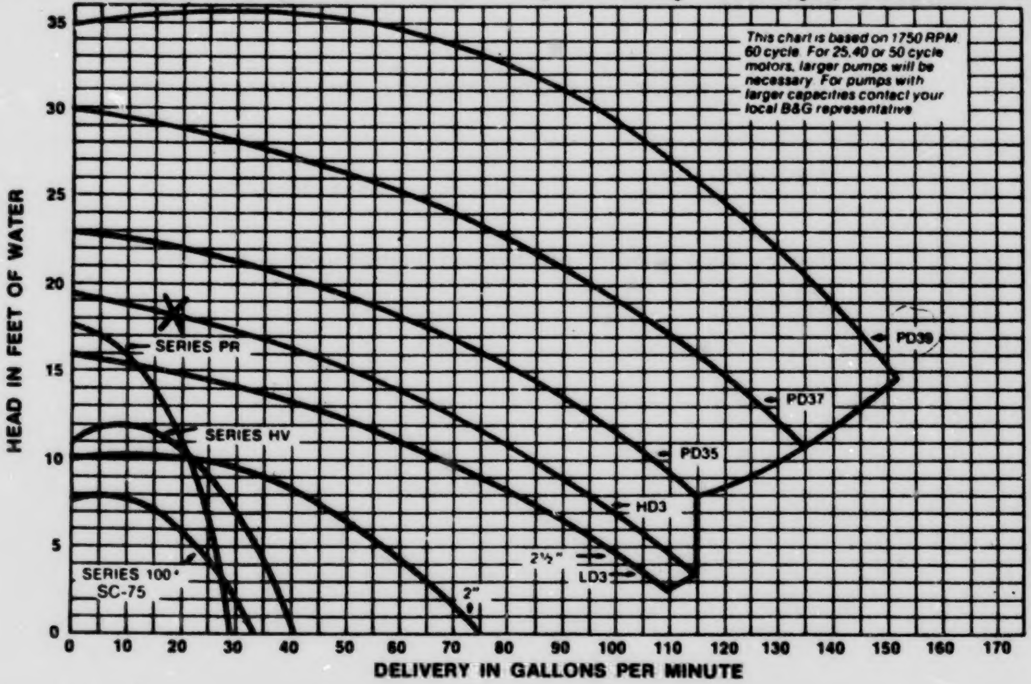
- all testing will be witnessed by the owner or his appointed representative and by the design consultant.

Scheduling

- the rotation test will be performed following the installation and wiring of the motor and the pump.

- perform the circulation test as soon as the system is filled with liquid.

E.G. INDUSTRIES
PUMP CURVE
FOR PRIMARY PUMP



IRON AND BRONZE BOOSTER PUMP

*Performance characteristics are based on using 1¼" or 1½" flanges. When using ¾" or 1" flanges performance will be slightly reduced.

This chart is based on 1750 RPM 60 cycle. For 25,40 or 50 cycle motors, larger pumps will be necessary. For pumps with larger capacities contact your local B&G representative

X = operating point

Direction of Rotation

- with the motor running, observe the end of the pump shaft to verify that it is running in the proper direction;
- if the pump is running backwards, connect the wires in the correct phase sequence.

Motor - Amperage

- with the motor operating, measure the current:

  Measured current ____________________

- the current should not exceed eighty percent of the nameplate rating.

Pump - Circulation Test

For each pump in the solar system, repeat this procedure:

- close the pump outlet valve;

- observe the pressures P_{in} and P_{out}. (See Figure 2.1.) The pressure difference across the pump (P_{out} - P_{in}) should be the maximum operating pressure for the pump, as specified by the manufacturer, or the zero flow rate pressure from the pump curve.

Pump No. 1	P_{in}	_______	kPa
Outlet valve closed	P_{out}	_______	kPa
	P_{out} - P_{in}	_______	kPa

- slowly, open the pump outlet valve;

- observe the output operating pressure P_{out}. The pump's output pressure should drop and remain at a pressure below the pump's stagnation pressure (P_{out} outlet valve closed). A drop in pressure and then a rise back to the stagnation pressure indicates a blockage in the system.

Outlet valve open	P_{out}	_______	kPa

5. Leak Test

- the system should be pressure tested with the working fluid if possible;
- if conditions do not allow the use of the working fluid, an air or dry nitrogen test may be used;
- every liquid loop system shall hold for fifteen minutes;
  - (a) without leakage, a water (glycol) pressure at least equal to the maximum pressure to which it may be subjected in service, or
  - (b) without a drop in pressure, an air pressure of not less than 700 kPa or the maximum working pressure of the lowest rated component;
- all leaks should be noted and repaired immediately;
- the system should be retested following any repairs to the system.

6. Final Visual Inspection

- check the collector for outgassing:
    - in many instances, condensation forms on the underside of the glazing; however, this should "bake" off after one or two sunny days;
- if the condensation fails to bake off, then the condensation could be the by-product of the gases given off by the collector. In this case, the inside of the collector glazing will have to be cleaned or the glazing will have to be replaced;
- if condensation has fallen onto the absorber surface, an iridescent effect may appear. This will not effect the collector's performance if it is merely the condensate of water; however, if it is from outgassing, the oil residue will have to be removed from the absorber surface to restore the collector's performance. Before attempting to clean the absorber surface, contact the manufacturer of the collector for advice;
- with the pump operating, verify the system flow by observing the flow indicator on the collector loop;
- verify that all manually operated valves are in the specified position (open or closed) required for normal operation of the system and that they have tags indicating the specified position;
- verify that the heat transfer fluid fill valve is sealed with a dated crimped seal.

7. System Flow Checks

Preliminary Information

- total collector loop flow required: 78 L/min
- obtain a copy of the manufacturer's pump curve for the pump;

Collector Loop Flow Rate

- if the system is provided with a proportional flow control system, it must be set to the maximum flow position;
- make sure the system is in an operating mode, with either the:
    - controller in the automatic position on a sunny day,
      or
    - controller in the manual position on an overcast day.
- check the flow indicator to verify that there is flow and that it is in the prescribed direction;
- the following test should be carried out for the pump in the collector loop;
    - measure the pressure differential across the pump;

      Measured pressure differential _________ kPa

    - from the manufacturer's pump curve, determine the operating point for the pump;
    - for this operating point, read off the operating flow rate;

      Flow rate as determined from pump curve _________ L/min

- adjust the flow by the means provided in the system until the flow rate is approximately equal to the specified flow rate;

- record the final operating flow rate:

Final operating flow rate __________ L/min

COMMISSIONING PROCEDURES

E.G. INDUSTRIES
DRAINBACK SYSTEM - SOLAR PROCESS HOT WATER

INDEX

1. General Introduction to Commissioning Document
    - Pre-conditions
    - Responsibilities
    - Scheduling

2. Verification of Pump Performance and System Flow Rates
    - Collector Loop Flow Rate

3. Heat Exchanger Effectiveness

4. Preliminary Thermal Performance Test

1. General Introduction to Commissioning Document

Commissioning is a demonstration by the consultant and the contractor to the owner that the solar system is operating in a safe and efficient manner. The solar system will undergo a series of tests and adjustments to meet or exceed a prescribed level of efficiency.

Pre-conditions

- it is assumed that start-up has been successfully completed;

Responsibilities

- the commissioning will be carried out by the consultant and the contractor in the presence of the owner or his representative.

Scheduling

- the system must have been in operation for a minimum of five days after the final start-up test before the system is commissioned.

2. Verification of Pump Performance and System Flow Rates

Collector Loop Flow Rate

- if the system is provided with a proportional flow control system, it must be set to the maximum flow position;

- make sure the system is in an operating mode, with either the:

  - controller in the automatic position on a sunny day,

    or

  - controller in the manual position on an overcast day.

- check the flow indicator to verify that there is flow and that it is in the prescribed direction;

- the following test should be carried out for the pump in the collector loop:

  - measure the operating amperage of the pump with a clamp-on ammeter;

    Measured amperage ___________

  - convert amperage to the equivalent horsepower using the following equation;

    Calculated horsepower ___________

$P = \sqrt{3}\, E\, I \cos \varphi$ (three phase)

where:

I = line current, amps

P = power, kW

E = line voltage, volts

$\cos \varphi$ = power factor

	Power Factor, cos φ three phase
1/2 HP or less	.75
1 - 2 HP	.75
2 1/2 - 15 HP	.80

1 HP = .7457 kW

- measure the pressure differential across the pump;

  Measured pressure differential __________ kPa

- from the manufacturer's pump curve, determine the operating point for the pump;

- for this operating point, read off the operating flow rate;

  Flow rate as determined from pump curve __________ L/min

- if the flow rate is not within twenty percent (plus or minus) of the specified flow rate, adjust the flow by the means provided in the system until the flow rate is within the allowable range, and record the new flow settings;

  Final operating flow rate __________ L/min

3. Heat Exchanger Effectiveness

- the test should be carried out using the normal hot water draw on the load side;
- the design hot water draw rate is 78 L/min;
- record the hot water draw rate during the test, if possible: _______ L/min
- with the pump operating, measure and record the following temperatures: (Note the schematic of the heat exchanger on the following page which indicates where to measure the required temperatures.)

T_P - drainback tank fluid temperature _____°C

$T_{S(in)}$ - secondary side inlet _____°C

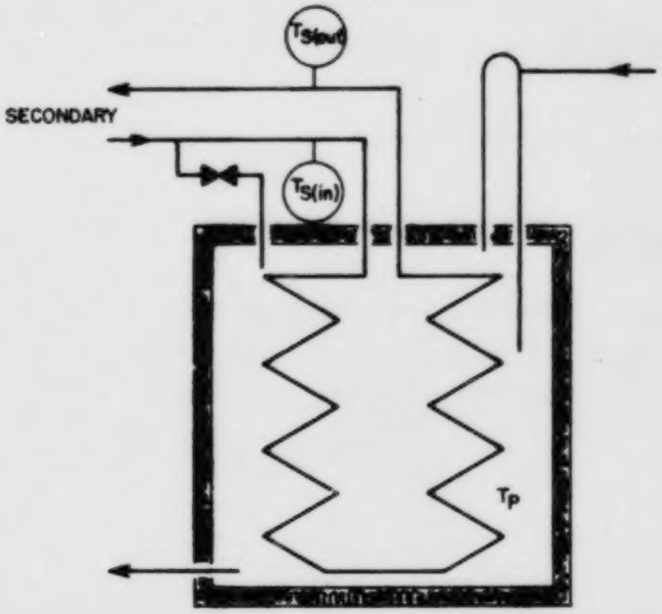
$T_{S(out)}$ - secondary side outlet _____°C

- calculate the heat exchanger effectiveness (E) using the following equation: (Note: coil-in-tank heat exchanger, coil is a section of the secondary loop)

$$E = \frac{T_{S(out)} - T_{S(in)}}{T_P - T_{S(in)}}$$

Heat exchanger effectiveness ______________

A problem is indicated if the effectiveness is not within the following range: _____, _____.



Schematic of Heat Exchanger

4. Preliminary Thermal Performance Test

The preliminary thermal performance test is undertaken in order to assess the operation of the solar system as a whole, and to compare the results with the performance that should be expected based on the collector manufacturer's claimed performance.

Perform the thermal performance test on a sunny day between 11:00 a.m. and 1:00 p.m. The storage temperature must be well below the maximum.

- Record the following measurements:

T_A - outdoor ambient temperature ________°C

$T_{C(out)}$ - collector return temperature ________°C*

$T_{C(in)}$ - collector supply temperature ________°C

F_S - total collector loop flow rate ________L/min

I - solar insolation ________W/m^2**

*The collector return temperature should be measured at the return header on drainback systems. This will ensure that the temperature is indicative of the heat transfer fluid and not a fluid/air mixture.

**The solar insolation should be measured using a hand held pyranometer. Measure the insolation during the test period. Hold the pyranometer against the surface of the collector when taking measurements.

Airport weather stations may be able to supply current solar insolation levels.

- determine the density and the specific heat of the collector heat transfer fluid:

where: c_p is the specific heat in J/kg°C

$$= \frac{\% \text{ water} \times 1 \text{ kg/L} + \% \text{ glycol} \times c_p \text{ glycol}}{100} = \_\_\_\_\_\_\_ \text{ kg/L}$$

$$= \frac{\% \text{ water} \times 4190 \text{ J/kg}^{\circ}\text{C} \times \% \text{ glycol} \times c_p \text{ glycol}}{100} = \_\_\_\_\_\_\_ \text{ J/kg}^{\circ}\text{C}$$

- calculate the temperature rise across the collector:

$$T = T_{C(out)} - T_{C(in)} = \_\_\_\_\_\_\_ {}^{\circ}\text{C}$$

- determine the heat gain:

where: ρ is the density in kg/L

$$Q = \frac{F_S \times \rho \times T \times c_p}{60} = \_\_\_\_\_\_\_ \text{W}$$

$$\frac{\text{L}}{\text{min}} \times \frac{\text{kg}}{\text{L}} \times \frac{\text{min}}{\text{s}} \times {}^{\circ}\text{C} \times \frac{\text{J}}{\text{kg } {}^{\circ}\text{C}} \times \frac{\text{W}}{\text{J /s}}$$

- determine the heat gain per unit of collector area:

$q = Q/A$
$= \_\_\_\_\_\_\_\_ \text{ W/m}^2$

- the efficiency is then:

$$\frac{q}{I} \times 100 = \underline{\hspace{2cm}}\%$$

- determine the manufacturer's claimed efficiency, for the given conditions, for series operation:

$$T_{reference} = \left[\frac{(N - 1)}{2N}\,(T_{C(out)} - T_{C(in)})\right] + (T_{C(in)})$$

$$= \left[.25 \times (T_{C(out)} - T_{C(in)})\right] + (T_{C(in)})$$

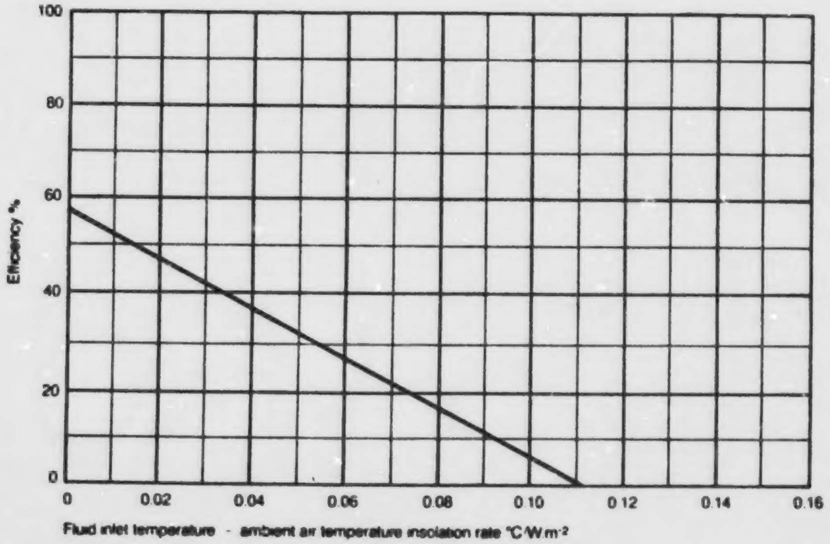
Where N = number of collectors in series = 2

$$\text{Operating point} = \frac{T_{reference} - T_A}{I}$$

- read the efficiency from the manufacturer's performance curve for this operating point.

Since the measured efficiency includes line losses, it can be expected to be slightly lower than the claimed efficiency for the collectors alone. However, the measured efficiency should not be more than twenty percent lower than the predicted value.

Collector Efficiency Curve



OPERATIONAL MONITORING DOCUMENT

E.G. INDUSTRIES
DRAINBACK SYSTEM - SOLAR PROCESS HOT WATER

INDEX

1. General System Description

2. System Operation

3. Introduction to Operational Monitoring

4. Operational Monitoring Procedures
    - Daily Operational Checklist
        - Pumps
        - System Pressures
        - System Temperatures
        - Fluid Level
        - General Overview
    - Monthly Operational Schedule
    - Semi-Annual Operational Maintenance Schedule
        - Fluid Quality
        - Heat Exchanger Effectiveness
        - Sensor Calibration Check
        - Preventative Maintenance

1. General System Description

This solar system is designed to heat 80 litres of water per minute. This hot water will enter the auxiliary steam heated boiler where it will be heated to 85°C - the temperature required for E.G. Industries' process. By utilizing solar energy to preheat the water, the heating cost will be reduced by approximately forty five percent.

Note the schematic of the solar hot water system. The system is made up of two major loops; the primary loop and the secondary loop.

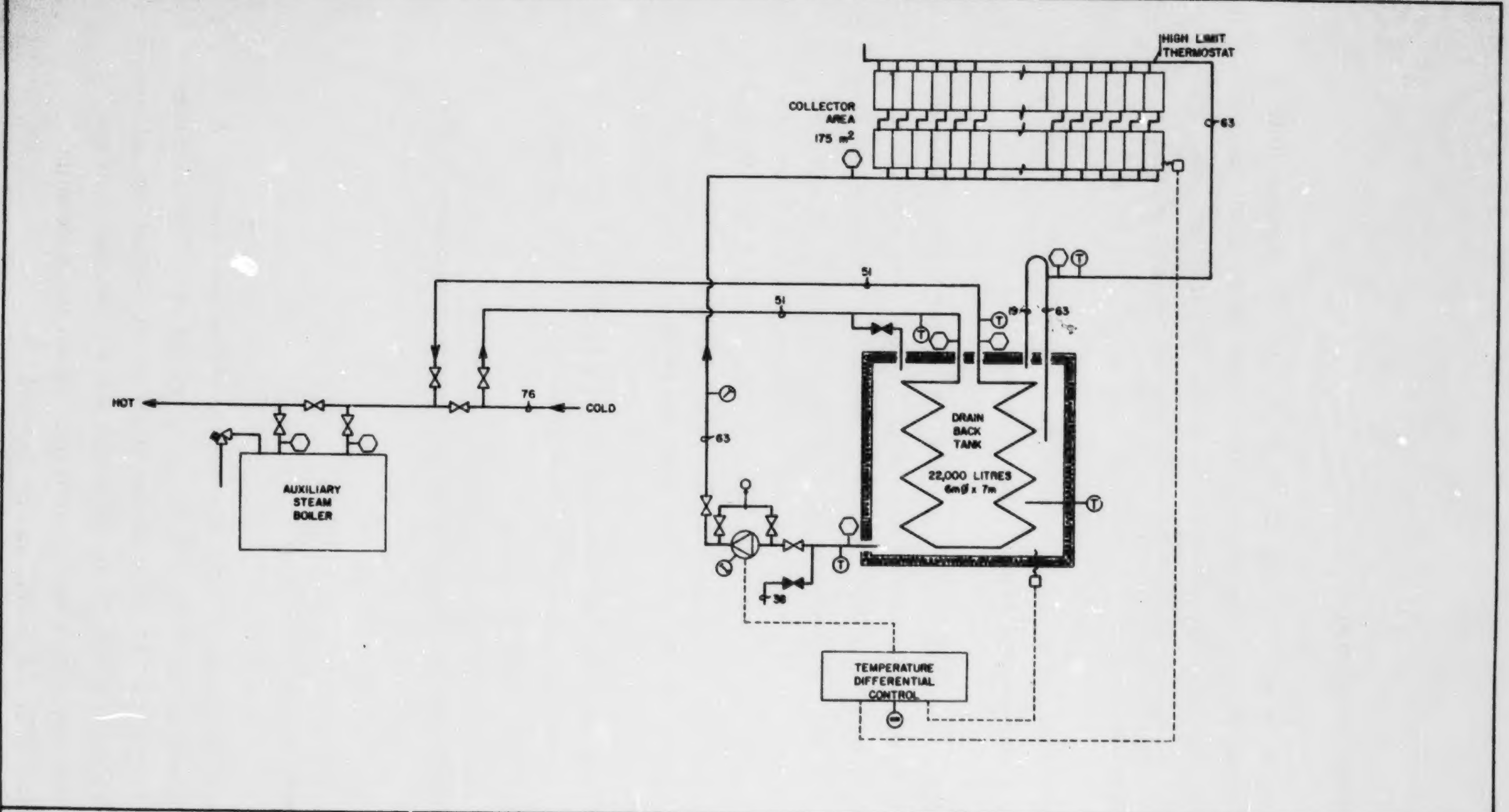
The primary loop is a drainback system containing treated water. When the pump is operating, the water circulates through the collectors where it is heated, and then through the drainback tank. The heat from the water is transferred to the water in the secondary loop which is piped through the tank. When the pump is not operating, the treated water drains back into the tank. Four gate valves are utilized in the loop. Two are used to isolate the pump from the rest of the system. The other two are normally closed -- one can be opened to fill the tank, the other can be opened to drain it.

The secondary loop contains the water that is being heated. Cold water is piped through the drainback tank which acts as an internal heat exchanger. Flow is controlled by a gate valve.

The preheated water is then heated up to the required temperature in the boiler.

2. System Operation

The primary loop circulates if there is enough available solar energy. A temperature differential control turns the pump on and off. The controller compares the temperature of the collector plates to the temperature of the water in the drainback tank. If the collectors are 8°C warmer than the water in the tank, the pumps will be activated. When the differential drops down below 2°C, the pumps will be shut off.



LEGEND

⊖	EVENT COUNTER	Ⓣ	TEMPERATURE PROBE
⊘	FLOW INDICATOR	⬡	PETERSON PLUG
⊘	RUN TIME METER	♀	PRESSURE GAUGE

DATE	JUNE, 1982
DESIGNED	S.B.
DRAWN	C.H.
CHECKED	J.R.

ACME ASSOCIATES
Engineers/Ingénieurs

E.G. INDUSTRIES

Solar Process Water Heating System

DRAIN BACK
SCHEMATIC WITH INSTRUMENTATION

SCALE	PROJECT NO.	DWG. NO.	REV
N.T.S	1443-81	4	

"SYSTEM B"

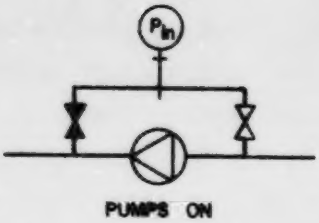
The instrumentation is noted on the schematic. The instruments are needed to monitor the system to make sure it is operating correctly and efficiently. There is an arrangement of two gate valves and a pressure meter around the pump to measure the pressure in and the pressure out. There is also a run time meter on the pump. An event counter is installed on the differential controller to count the number of times the solar system switches on and off. A flow indicator is situated in the primary flow loop. Temperature probes are installed in the lines going into and coming out of the "coil-in-tank", as well as, in the tank to measure the temperature of the solar heated water. Peterson plugs, into which temperature and pressure probes can be inserted, are positioned as indicated.

In order to follow the operational monitoring schedule, the following measurements must be understood:

- number of cycles: During the course of a day, the solar system is turned on (pump on) by the control system when sufficient solar energy is available. When the amount of energy drops to the point where operating the system is no longer practical, the controller turns off (pump off) the solar system. Every time the controller turns the system on or off, an "event" is counted on the "event counter". It is important that the controller turns the pump on and off at the appropriate conditions and, therefore, does not cause the system to cycle excessively. To verify that the controller is working properly, the "number of events" for a period are checked. Note: the event counter cannot be reset so the additional events over a period must be calculated.

- inlet pump pressure:

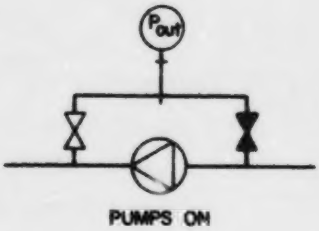
The inlet pressure is the pressure of the liquid in the piping system just upstream of the pump when it is operating.



The inlet pressure will be measured in the primary loop. With the pump on and the gate valve just downstream from the pressure gauge closed, measure the inlet pressure.

- outlet pump pressure:

The outlet pressure is the pressure of the liquid in the piping system just downstream of the pump when it is operating.

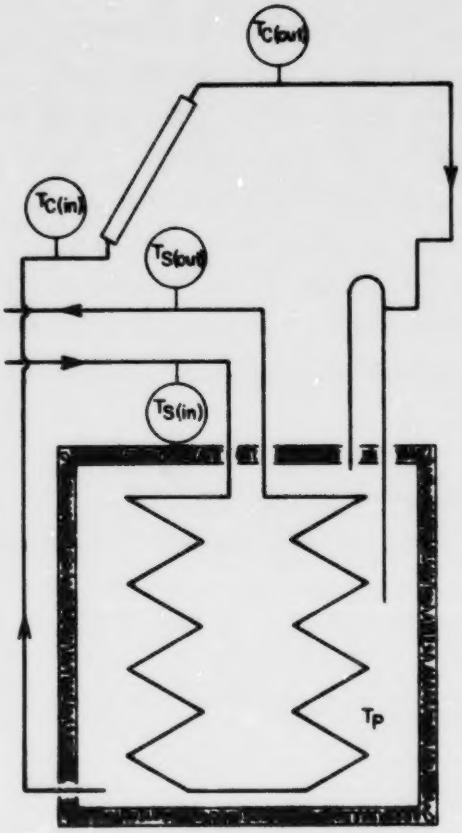


The outlet pressure will be measured in the primary loop. With the pump on and the gate valve just upstream from the pressure gauge closed, the pressure gauge measures the outlet pressure.

- pump run time:

The run time meter attached to the pump clocks the time the pump is operating. This information is used to ensure that the system is operating close to the expected amount of time. Note: The run time meter cannot be reset so the additional hours over a period must be calculated.

- temperatures:



There are several permanently installed temperature probes with a digital readout:

- temperature of water in the primary loop after it has been heated by the collectors, $T_{C(out)}$,
- temperature of the water in the primary loop before it has been heated by the collectors, $T_{C(in)}$,
- temperature of water in drainback tank, T_P,
- temperature of water in the secondary loop before entering the heat exchanger, $T_{S(in)}$,
- temperature of water in the secondary loop after leaving the heat exchanger, $T_{S(out)}$.

- system alarms:

The high limit thermostat sets off an alarm if the temperature of the fluid leaving the collector is greater than 95°C.

3. Introduction to Operational Monitoring

The prime purpose of operational monitoring is to detect a decrease in the solar system performance. This is done by regularly comparing certain indicators, such as temperatures, pressures and pump run times with those specified in the design and commissioning process. A change in these indicators to outside the design range means that the system has an operational problem. Identifying operational problems or system breakdowns as soon as possible is important in reducing damage to the system, and will also maximize the energy output of the solar system. Early detection of problems will also increase the life of the system, and keep operating and maintenance costs to a minimum.

Checks of instrument readings and verifications of the operation or condition of component equipment are conducted on a set of schedules as follows:

- daily,
- monthly, and
- semi-annually or yearly.

4. Operational Monitoring Procedures

Daily Operational Checklist

To ensure that no major malfunction of the solar system has occurred, the following questions should be considered daily. If the answer to any of the questions is "no", a problem has been detected. To determine the cause of the problem and the required action, see the Operator's Troubleshooting Guide.

Pump

1. If the weather is sunny, or partially sunny, is the pump operating?
2. If there is no sun, is the pump off?

3. If the pump is operating, is the period of operation reasonable? A problem is indicated if the event counter indicates more than 10 cycles per day.

System Pressures

4. If the pump is operating, is the change in pressure across the pump in the specified range? (low, high) (acceptable range (P_{out} - P_{in}): 48 kPa to 53 kPa)
5. If the pump is operating, is the discharge pressure (P_{out}) relatively constant the pump? (maximum deviation = 5 kPa)

System Temperatures

6. If the pump is operating, is the rise in temperature between "storage to collector" and "collector to storage" within the specified range? (acceptable rise in temperature: 1 °C to 8 °C).

Fluid Level

7. If the system is not operating, is the fluid level in the draindown tank within the acceptable range? (acceptable level range within 2 cm of marked line)

General Overview

8. Does the status of all system alarms indicate normal system operation?
9. Has the pressure relief valve remained closed?
10. Are the vibration and noise levels normal?
11. Is the temperature of all mechanical equipment normal? (no overheating)

Monthly Operational Schedule

Every month a more detailed version of the "daily checks" will be performed and recorded in the chart shown on the following page. This procedure will provide an historical record of the solar system's performance as well as a closer examination of the system to check for possible problems. The monthly checks should be done on a day when solar energy is available and the system is cycling. Use the following procedure to obtain the values for the chart.

(a) Fill in general information; name, date, time, weather description and outside temperature.

(b) For each pump module:

Read and record the pump run time. Subtract the previous month's reading to find the monthly pump run time. Compare this with the expected value for the month. Being high or low may be a result of abnormal weather, but may also be an indication of problems.

Read and record the pump discharge pressure (P_{out}), and the pump suction pressure (P_{in}).

Calculate and record the pressure difference across the pump ($P_{out} - P_{in}$).

(c) Read and record the following temperatures:

- Drainback tank fluid temperature	T_P
- Secondary circuit heat exchanger: in	$T_{S(in)}$
- Secondary circuit heat exchanger: out	$T_{S(out)}$
- Solar storage tank: top, bottom	

Calculate ($T_{P(in)} - T_{P(out)}$) and ($T_{S(out)} - T_{S(in)}$). Record.

MONTHLY OPERATIONAL RECORD

E.Q. INDUSTRIES

				WEATHER		PUMP MODULE NO.1							PUMP MODULE NO.2							TEMPERATURES (°C)								TEMPERATURES (°C)								Control Module		Drain Down System	
						Run Time (hrs)			Pressure (kPa)				Run Time (hrs)			Pressure (kPa)				Heat Exchanger No. 1						Solar Storage Tank		Heat Exchanger No. 2						Solar Storage Tank					
OPERATOR	MONTH	DAY	TIME	CLEAR, VARIABLE, or OVERCAST	OUTDOOR TEMP (°C)	TOTAL	MONTHLY	EXPECTED	P_S	P_{out}	P_{in}	$P_{out} - P_{in}$ 48 [illegible]	TOTAL	MONTHLY	EXPECTED	P_S	P_{out}	P_{in}	$P_{out} - P_{in}$	PRIMARY In $T_{P(in)}$	PRIMARY Out $T_{P(out)}$	SECONDARY In $S(in)$	SECONDARY Out $T_{S(out)}$	$T_{P(in)} - T_{P(out)}$	$T_{S(out)} - T_{S(in)}$	TOP	BOTTOM	PRIMARY In $T_{P(in)}$	PRIMARY Out $T_{P(out)}$	SECONDARY In $T_{S(in)}$	SECONDARY Out $T_{S(out)}$	$T_{P(in)} - T_{P(out)}$	$T_{S(out)} - T_{S(in)}$	TOP	BOTTOM	EVENTS TO DATE	EVENTS FOR MONTH max 300	TIME TO DRAIN (min) 3	LEVEL (from line) +2 −2
	Jan.							90																															
	Feb.							120																															
	Mar.							120																															
	Apr.							180																															
	May							240																															
	June							240																															
	July							210																															
	Aug.							210																															
	Sept.							180																															
	Oct.							160																															
	Nov.							120																															
	Dec.							90																															

SYSTEM FAILURE REPORT

OPERATOR	DATE	DESCRIPTION

(d) For each control system module, read and record the number of events to date. Calculate the number of events for the month and compare it to the acceptable range.

(e) Manually stop the pump and record the time taken for the fluid to completely drain. Measure and record the fluid level.

(f) Analysis of monthly record:
Compare all readings and calculated values to their specified ranges. If they are outside of the range, consult the Operator's Troubleshooting Guide.

(g) The following preventative maintenance checks should also be performed:

- clean collector glazing where necessary,
- inspect collectors for the following:
    - weep holes full of debris, insects, ice, etc.,
    - deterioration of the absorber plate in the form of discolouration or buckling,
    - permanent condensation on the underside of the collector glazing,
    - temperature variance: a collector that is noticeably cooler or warmer than the others indicates a flow blockage or imbalance (a heat meter reading of the collector surface temperature will do),
- check mounting hardware security and caulking as well as flashing around roof penetrations,
- lubricate pumps, motors and control linkages as required.

Semi-Annual Operational Maintenance Schedule

Semi-annual checks will be conducted each spring and fall. The schedule includes several repeats of test procedures that were done as part of the start-up and commissioning, along with preventative maintenance checks.

Fluid Quality

To control the entry of corrosion causing oxygen into the water of the collector loop, some drainback systems use an oil film on the top of the water in the drainback tank. If this is used, check the oil film thickness and replenish, if necessary.

If alternate corrosion inhibitors are utilized, check them according to the manufacturer's recommendation.

Heat Exchanger Effectiveness

The test should be carried out using the design hot water draw on the load side.

The design hot water draw rate is 78 L/min.

With the pump operating, measure and record the following temperatures;

T_P - drainback tank fluid temperature ______ °C

$T_{S(in)}$ - secondary side inlet ______ °C

$T_{S(out)}$ - secondary side outlet ______ °C

Calculate the heat exchanger effectiveness (E) using the following equation: (Note: coil-in-tank heat exchanger, coil is a section of the secondary loop)

$$E = \frac{T_{S(out)} - T_{S(in)}}{T_P - T_{S(in)}}$$

Heat exchanger effectiveness __________

A problem is indicated if the effectiveness is not within the following range: .68 , .75 .

Sensor Calibration Check

Sensor accuracy can change with time due to the build up of corrosion at the attachment points or the lead connections. Sensor accuracy can also be distorted when it experiences temperature extremes that exceed its design range. Since combined inaccuracies in both the collector and storage sensor inputs can significantly reduce the system performance, sensor calibration checks should be performed semi-annually.

A total of four tests are required:

1. collector sensor at cool temperature (early in morning on cloudy day),
2. collector sensor at hot temperature (mid to late afternoon on sunny day),
3. storage tank sensor at cool temperature,
4. storage tank sensor at hot temperature.

For each test, measure the temperature at the point and the resistance at the control connection. Compare the readings to the temperature-resistance curve supplied by the manufacturer. If there is a discrepancy, corrosion or extreme temperatures could have damaged the sensor or its connections. Check both and replace, if necessary, then repeat the test.

Preventative Maintenance

- Clean filters and strainers
- Cycle or operate valves to assure functioning
- Oil or lubricate components according to the manufacturer's recommendations
- Check charge on expansion tank

TROUBLESHOOTING GUIDE

E.G. INDUSTRIES
DRAINBACK SYSTEM - SOLAR PROCESS HOT WATER

TROUBLESHOOTING GUIDE

Symptom	Source	Cause	Action
No hot water	Make-up water shut-off valve	Valve closed	Open valve.
	Auxiliary heater	Failed to activate	Check breaker or fuse. Check power to heater. Check fuel supply.
Hot water temperature too low	Hot water thermostat	Thermostat setting too low	Set thermostat higher.
	Auxiliary heater	Not functioning	Check breaker or fuse. Check and repair auxiliary heating unit and fuel supply.
	Temperature modulating valve	Faulty	Repair or replace.
		Temperature set too low	Reset.
Water temperature too high	Hot water thermostat	Thermostat setting too high	Reset.
		Thermostat out of calibration	Recalibrate.
	Temperature modulating valve	Faulty	Repair or replace.
		Temperature set too high	Reset.
Insufficient hot water to load, but solar system seems normal	Auxiliary heater	Auxiliary heater problems	Check auxiliary heater, wiring, gas, oil lines, burners, and set points.
	Valves	Isolation valves improperly closed	Set in proper positions.
	Temperature modulating valve	Improperly adjusted	Check adjustment. Adjust as necessary.
		Faulty	Repair or replace.

Symptom	**Source**	**Cause**	**Action**
Drop in water pressure at both hot and cold outlets	Inlet water pressure	Inlet strainer clogged	Clean basket.
	Pressure reducing valve	Malfunctioning	Check for plugged ports, and proper operation. Clean, repair, or replace.
Drop in water pressure at hot outlets only	Valves	Valve improperly closed	Open manual valves Check automatic valve operation, repair or replace.
		Jammed check valve	Repair and replace.
	Strainers	Flow restriction	Check and clean.
System does not start or Pump not running when solar energy available	Power supply	Control switch in "off" position	Turn to "auto" position.
		No power to pump	Check fuses or circuit breaker. Check wiring and connections.
		No power to controller	Check fuses or circuit breaker. Check wiring and connections.
	Pump	Pump seized	Try turning by hand. Repair or replace.
		Motor failure	Repair or replace.
	Controls	Control failure	Try on "manual". If pump runs suspect control system. (Refer to Troubleshooting Controls)
		Pressure cut offs activated	Rectify cause, reset.
		Temperature cut off activated	If tank temperature below high limit cut off, check control system. (Refer to Troubleshooting Controls)
		Fault in control system	Check control system. (Refer to Troubleshooting Controls)

Symptom	Source	Cause	Action
		Electrical problem	Check line terminal voltage.
Pump running when no solar energy available	Control system	Control set on "manual"	Set on "automatic".
		Fault in control system	Check control system. (Refer to Troubleshooting Controls)
Pump cycling excessively	Controls	Incorrect set points	Check set point.
		Fault in control system	Check control system. (Refer to Troubleshooting Controls)
System static pressure low	Charge pressure low	Fluid level low	See "Fluid level low".
	Expansion tank (Diaphram)	Bladder capacity exceeded or diaphram leaking	Inspect for fluid in air chamber, replace expansion tank.
	Expansion tank (Standard)	Inadequate air space	Adjust liquid level.
		Air leak	Find and correct.
Fluid level low	Leak in system	Piping leak	Repair. Replace wet insulation.
		Leak from drain	Close drain tightly, add cap.
		Leak from air vent	Inspect, clean mechanism, repair or replace.
	Pressure Relief valve	Relief valve has expelled excess pressure	Find cause for excess pressure; correct. Recharge system to operating pressure.
System static pressure high	Controls	Overtemperature	Find cause. (Refer to Troubleshooting Controls)
	Fluid	System overfilled	Check level.
	Expansion tank	Expansion tank is waterlogged	Check expansion tank liquid level. Check for air leak.

Symptom	Source	Cause	Action
Pump discharge pressure fluctuating	Pump	Cavitation	Find source of air entry, check for restriction on suction side, clean strainer.
System does not drain	Vacuum breaker	Damaged	Replace.
		Frozen	Thaw and protect from freezing.
	Piping	Piping not sloped adequately	Correct.
		Vent tube blocked	Check and clear.
	Controls	Control and sensor fault	(See "Troubleshooting Controls")
	Solenoid or motorized valve	Actuator defective	Replace.
		No power to actuator	Check wiring.
		Valve sticks	Repair or replace valve.
System will not fill with pump running	Pump	Cavitation	Check for air entry, check for restriction on pump suction side, clean strainer. Check for low fluid level in drain back tank.
System drains continuously with pump running	Drain down valve will not close	Actuator defective	Replace.
		Power	Check wiring.
		Valve sticks	Repair or replace valve.
	Freeze protection thermal switch	Set point drift	Reset or replace.
		Defective	Replace.
		Loose contacts	Reconnect.
	Control sensors	Out of calibration	Recalibrate.
		Defective	Replace.

Symptom	Source	Cause	Action
Pressure does not drop when system filled (syphon type drain back system)	Piping	Leak in pipes causes break in syphon	Find and seal.
		Major flow restriction in system	Check position of all valves.
	Vacuum breaker	Faulty	Replace.
		Frozen	Thaw and protect from freezing.
	Fluid	Leak has reduced fluid level	Seal leak; refill system.
	Pump	Impeller fouled or damaged to point that pump cannot overcome static head	Clean or repair pump.
Storage temperature decays during periods of no load	Insulation	Damaged or wet	Repair or replace.
	Check valve	Reverse thermosyphoning	Inspect check valve operation. Repair or replace.
Storage temp remains high during high load, little solar	Valves	Isolation valves improperly closed	Set in proper position.
Poor solar energy collection	Collector array	Film on collector glazing	Check for dirt on glazing. Check for condensation and outgassing. Clean glazing.
		New source of shading	Check for new structures growth of trees, etc.
		Flow rate	Check flow rate. Reset to specified flow.
			Check operation of automatic flow control valve. Repair or replace as necessary.
		Flow balance	Check balance of flow through collector banks. Rebalance as necessary.
			Check operation of automatic flow control valves. Repair or replace as necessary.

Symptom	Source	Cause	Action
		Scale forming in collector tubes	Flush collector loop.
	Piping	Insufficient or damaged insulation	Check condition and adequacy of insulation. Repair, replace or add additional insulation.
	Collector fluid	Reverse thermosiphoning	Inspect check valve operation. Repair or replace.
	Controls	Out of calibration	(See "Troubleshooting Controls")
Excessive vibration or noise in system	Pump	Cavitation	Check for air entry, check for resriction on pump suction side, clean strainer.
		Bearings	Check for hot or worn bearings. Check bearing alignment.
		Impeller	Inspect for misaligned shaft, repair, replace. Check balance of impeller. Clean, repair or replace.
	Piping	Entrapped air	Check automatic air vents. Vent manually. Force purge system, find and correct source of air entry.
		Supports	Check condition and adequacy of hangers. Repair hangers or install additional hangers.
Water hammer	Automatic valves	Open or close too fast	Install valves with slower action. Modify controls to slow valve action.

The following section of the diagnostic chart will be helpful if either the pump operating pressure or the system ΔT as defined in the operators manual are out of the specified range

Pump discharge pressure not design range	If this condition is found carry out the following check: 1. Using the pump inlet pressure and the pump discharge pressure, determine the pressure difference across the pump (P).

Symptom	Source	Cause	Action
ΔP high		Generally the result of a flow restriction of some type	
	Valves	Flow control valves tampered with (closed)	Check seal on valves, if tampered with adjust flow as per commissioning procedure.
		Shut-off valves closed	Open.
		Automatic valves closed	Check controls, operation, and springs, repair or replace.
	Check valve	Jammed	Repair or replace.
	Air vents	Faulty -- causing air lock	Operate needle valve manually; check float control, inspect, clean, repair or replace.
	Collector	Passages clogged	Feel if some collectors hotter than others. Remove collector, backflush passages.
	Strainer	Flow restriction	Check and clean strainers.
ΔP Low	Valves	Flow control valves tampered with (closed)	Check seal on valves, if tampered with adjust flow as per commissioning procedure.
	Three-way valves	Internal leaking	Check and repair.
	Pump	Cavitating	Find source of air entry. Check for flow resriction on suction side, clean strainer.
		Mechanical failure	Check and repair.

Symptom	Source	Cause	Action
ΔT low ΔP normal	Collectors	Dirty	Clean surface.
		Insulation wet	Dry or replace insulation., Reseal collectors.
		Excessive condensation	Inspect seal, pipe gaskets, and weep holes. Repair.
	Pipe or tank insulation	Damaged, wet or missing	Repair or replace.
	Heat exchanger	Scaled up	Clean heat exchanger.
	Controls	Setting incorrect or drifting	Reset. (See "Troubleshooting Controls")
ΔT low ΔP low	Flow control valves	Tampered with (opened)	Check seals on valves, if tampered with adjust flow as per commissioning procedure.
	Three-way valves	Internal leaking	Repair.
	Controls	Incorrectly set	(See "Troubleshooting Controls")
ΔT high ΔP normal	Controls	Incorrectly set	(See "Troubleshooting Controls")
ΔT high ΔP low	Pump	Cavitation	Find source of air entry, correct, clean strainer, check for restriction on suction side.
		Impeller damage	Check stagnation pressure. Repair.
	Three-way valves	Internal leak	Check and repair.

Symptom	Source	Cause	Action
ΔT high ΔP high		Generally the result of a flow restriction of some type.	
	Valves	Flow control valves tampered with (closed)	Check seal on valves. If tampered with adjust flow as per commissioning procedure.
		Shut-off valves closed	Open.
		Automatic valves closed	Check controls, operation, and springs. Repair or replace.
	Check valve	Jammed	Repair or replace.
	Air vents	Faulty -- causing air lock	Operate needle valve manually; check float control, inspect, clean, repair or replace.
	Collector	Passages clogged	Feel if some collectors hotter than others. Remove collector, backflush passages.
	Strainer	Flow restriction	Check and clean strainers.
Pump run time too high			(See "Pump(s) running when no solar energy available")
Pump run time too low			Check T and P(s) and refer to appropriate section, if cause not evident, refer to See "System Diagnostic Procedures".

TROUBLESHOOTING SOLAR CONTROLS

In troubleshooting solar controls, it is important to use a logical and systematic approach in isolating and correcting system faults. The following is the recommended procedure. This procedure is for variable resistance type controllers. For I.C. controllers, which use variable voltage sensors, voltages are measured instead of resistances.

Differential Controller Checks

1. Check power supply to controller.

2. Check that all components are wired correctly to controller (according to manufacturer's specifications).

3. If the pump or valve does not work in the "manual" mode, disconnect it from the controller and apply rated voltage to its input wires at the controller.

    a. If it runs, the pump is all right - the problem is in the control system.

    b. No operation - the pump or valve is faulty or the interconnecting wiring or relay is faulty. Isolate the fault and repair or replace the defective component.

4. Check all sensors for:

    - proper location,
    - secure attachment with no corrosion build-up,
    - proper wiring to controller.

5. Check each sensor for proper resistance by disconnecting it at the controller. If the measured resistances are as specified,

the fault is a controller problem. Proceed to Step 8. If the measured resistances do not correspond to the specification value for the temperature of the sensor location, then:

- the sensor is faulty,
- the interconnecting wiring is faulty.

6. Disconnect sensor from wiring leading to the controller. Check the sensors resistance at this point. If the resistance is not to specification, replace the sensor.

7. If sensor is accurate, check for corrosion at all wiring connections. Clean, reconnect and remeasure resistance at the controller. If the measured resistance is still not correct, replace the wiring between the sensor and the controller.

8. Controller operational check.

   - switch off the electrical power to all pumps and/or control valves and make sure the controller is set for the recommended temperature differential;

   - replace the temperature sensors at the collector and the tank with variable resistors (variable resistors with readouts will simplify the procedure). The resistors can be connected to the sensor terminals at the controller;

   - from the temperature sensor characteristic curve, determine the resistance associated with 5°C absolute temperature;

   - dial this resistance into the variable resistor on the output to the tank sensor. Record the resistance;

- with the controller set in the automatic position, gradually change the resistance on the collector side until an output is measured at the controller output terminals (to pump or control valve). Record the indicated resistance;

- vary the resistance until there is no longer an output at the controller output terminals. Record the indicated resistance;

- reset the tank variable resistor for the resistance associated with a 15°C absolute temperature;

- repeat the above procedure determining the collector resistance to receive an output at the output terminal and the resistance to receive no output. Record both resistances;

- calculate the differential resistance, and from the temperature sensor characteristic curve determine the temperature differential;

- compare this with the original setting of differential temperature;

- if the two figures disagree substantially (more than ten percent), adjust the controller setting and repeat the above test.

9. Sensor Calibration Check

Preparation

1. Obtain a copy of the temperature sensor characteristic curve from the appropriate manufacturer (resistance vs. temperature).

2. Obtain a digital multimeter with an appropriate probe to determine as accurately as possible the temperature at the point the sensor is intended to sense.

Method

Determine the temperatures at the points the sensor is intended to sense. These will likely be the absorber plate in one of the collectors and the temperature in the lower third of the storage tank.

Measure with an ohm meter the resistance shown by the sensor. This should be done at two temperatures for each sensor, for example:

For collector sensors:

1. Cool Temperature - as early as possible in the morning, preferably on a cloudy day.

2. Hot Temperature - mid to late afternoon on a sunny day.

For storage tank sensors:

1. Cool Temperature - after a major draw of heat from storage to load on a cloudy day and before the auxiliary heat has replenished the draw (where applicable).

2. Hot Temperature - late on a sunny day before a major draw of heat or on a day when the load is reduced.

Compare the measured resistance with that shown on the manufacturer's table or graph for the appropriate temperature.

If the resistance varies from the expected value, the sensor or sensor lead connections may be corroded or the sensor may have been damaged by heat extremes. Check both and replace as necessary then repeat the test.

High Temperature Limit Protection

High temperature limit switches are used in solar systems either to protect collectors, storage tanks or as a secondary safeguard against failure of the mixing valve on the outlet to load.

Co

not inhibit the initial start up of the collector loop pump, but will activate if, after a reasonable length of time, the collector temperature has not fallen.

For closed loop glycol systems, the high temperature limit or control logic may be used to divert flow to a heat purge coil.

High Temperature Protection or Storage Tanks

High temperaturelimit switches are used to protect storage tanks from over temperature conditions. In some cases, a tank temperature limit can serve as a secondary protection against scalding temperatures being delivered to load if the mixing valve fails.

High Temperature Limit Switch Checkout

The checkout procedure is similar to that for freeze protection. The swich or sensor is immersed in hot water, which is heated until the device activates and then cooled until it reverses. The temperatures and resistances for these points are recorded and checked against the spcifications.

GENERAL SYSTEM DIAGNOSTIC PROCEDURE

The performance of a solar system depends on the interaction of all system components, outside conditions, and the load imposed on the system.

There are cases in which a general decrease in the performance of a system is indicated by a decrease in system operating time, temperature differences, measured energy collected, or by an increase in the required auxiliary energy. In some cases, the particular problem cannot be isolated by the operator. The following is a general diagnostic procedure which can, in most cases, isolate the causes.

Carrying out this procedure requires some knowledge of solar systems and a number of portable instruments; therefore, a troubleshooting technician or engineer may be required.

1. The first step is a visual inspection of the system paying special attention to such items as completeness and condition of insulation and whether the collectors are clean and free of new shading.

2. Verifying flow rates.

   The operating flow rates in each loop should be checked by the means provided. This may be by using pump differential pressures or by reading a flow meter if one is installed in the particular loop. (See commissioning procedure.)

3. If the flow rate in any loop in the system is lower than specified, the flow restriction can be isolated by checking the pressures at the monitoring points provided in the system and comparing these with the commissioned values.

4. If the flow rates in all points of all loops are as specified, check the fluid temperatures at each monitoring point on a clear sunny day.

5. Verify the flow balance through the collector banks.

   The face temperature of each collector should be checked by feel or, preferably, with a pyrometer. Collectors that are significantly warmer or cooler than their neighbours indicates flow blockages and stagnation or high flows respectively.

   It is a good idea to check the bank temperature balance by the method shown in the commissioning procedure.

6. Verify the effectiveness of the heat exchanger as in the commissioning procedure. A reduced effectiveness could indicate scaling of the heat exchanger surfaces.

7. Perform the preliminary thermal performance test as shown in the commissioning procedure and compare the efficiency with the commissioned values. This will detect degradation of the collectors' performance.

8. Check the calibration of the control system as described in "Troubleshooting Solar Controls."

If satisfied that the operating characteristics of the system are normal, investigate the non-operating features.

9. Isolate the system from load and bring the storage temperatures up during the day. Read the storage temperature at nightfall and shut off the system. Check the storage temperature in the morning. If the storage temperature has dropped significantly, suspect damaged or wet insulation, or reverse thermosyphoning (usually the result of a faulty check valve).

PERFORMANCE MONITORING

E.G. INDUSTRIES
DRAINBACK SYSTEM - SOLAR PROCESS HOT WATER

One meter is required to determine the overall performance of the solar heating system. The selected meter is a:

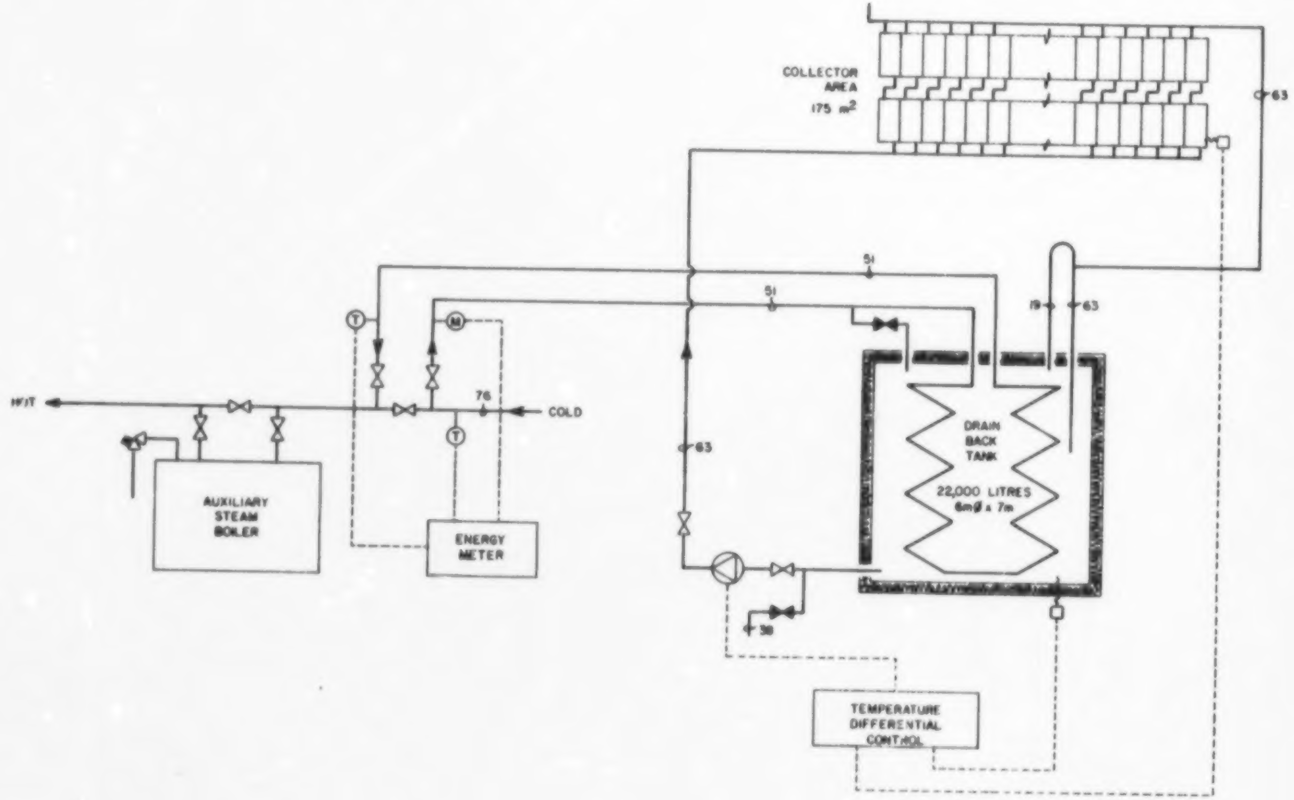
VALMET Heat Meter
Model: 5EV-01-10
- with 2 inch flow meter
- with matched temperature sensors

available from:

AALTO Equipment Limited
500 Duplex Avenue
Suite 1503
Toronto, Ontario
(416) 484-0729

Note the figure illustrating the arrangement of the performance monitoring equipment.

A sample form, on which this performance data will be recorded each month, is attached.



LEGEND

Ⓣ TEMPERATURE PROBE

Ⓜ FLOW METER

DATE JUNE, 1982	
DESIGNED	S.B
DRAWN	C.H
CHECKED	J.R

ACME ASSOCIATES
Engineers / Ingénieurs

E.G. INDUSTRIES

Solar Process Water Heating System

Schematic with
Performance Monitoring Equipment

SCALE	PROJECT NO	DWG. NO	REV
NTS	1443-81	5	

"SYSTEM B"

PUSH MONITORING MONTHLY REPORT

PROJECT NAME: E.G. Industries

PUSH PROJECT NUMBER: 234567891

DATE:

Please fill in energy quantities indicated below:

SOLAR ENERGY INPUT (meter number)

RECORD OF SYSTEM PROBLEMS:
(Briefly explain any system problems encountered)

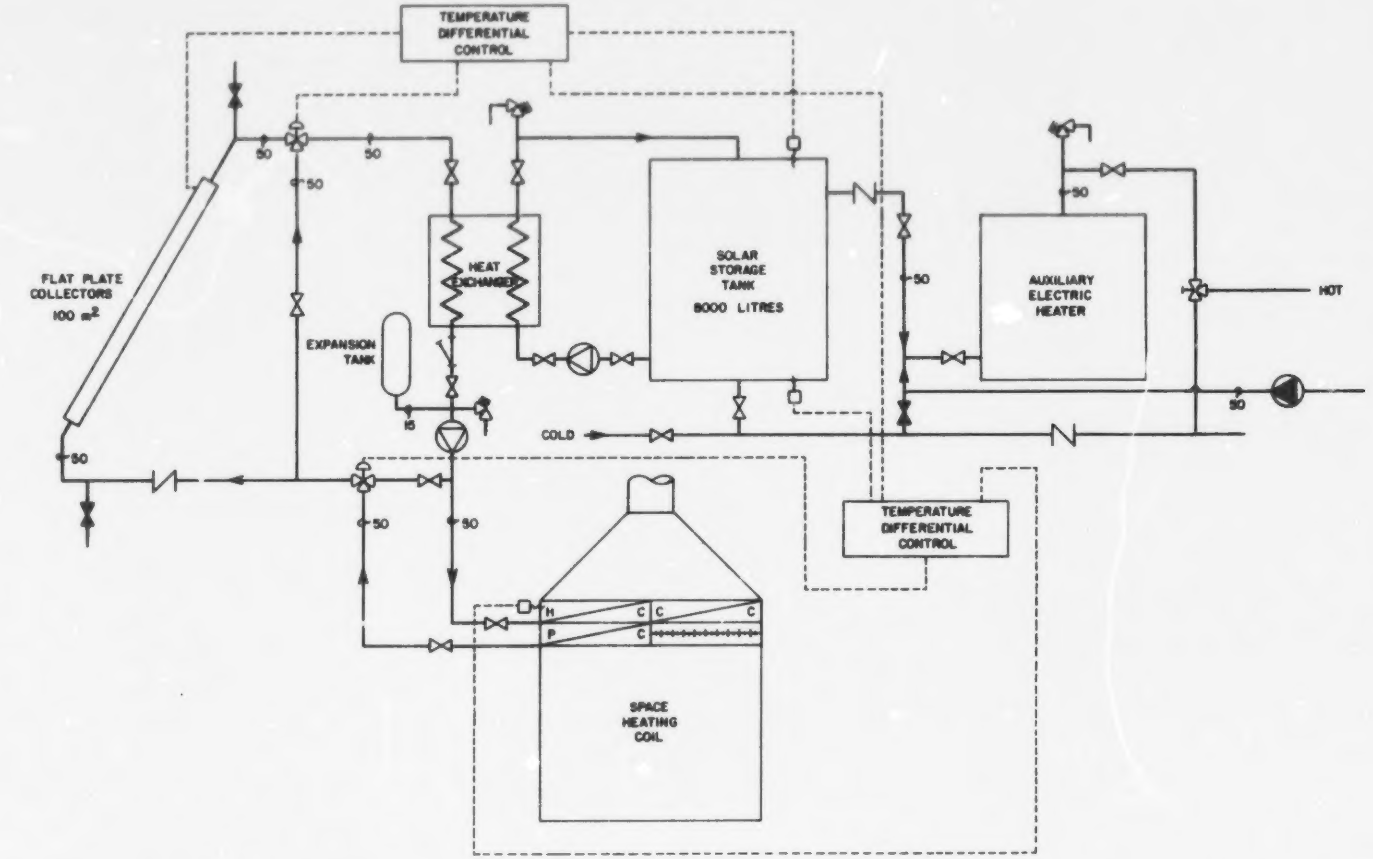
EXAMPLE SYSTEM "C"

GRAYSTONES PUBLIC SCHOOL

Solar Space and Domestic Hot Water Heating System

This system is a relatively complex combined space and water heating system with a closed glycol collection loop. Space heating is accomplished using a fan coil unit in the glycol loop.

Auxiliary water heating is electric.


TEMPERATURE DIFFERENTIAL CONTROL
50
50
50
FLAT PLATE COLLECTORS 100 m²
HEAT EXCHANGER
EXPANSION TANK
15
SOLAR STORAGE TANK 8000 LITRES
50
AUXILIARY ELECTRIC HEATER
50
HOT
50
COLD
50
50
50
TEMPERATURE DIFFERENTIAL CONTROL
H
C
C
C
P
C
SPACE HEATING COIL

DATE MAY, 1982
DESIGNED S.B.
DRAWN C.H.
CHECKED J.R.

ACME ASSOCIATES
Engineers/Ingénieurs

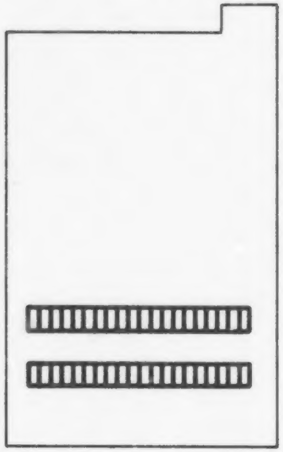
GRAYSTONES PUBLIC SCHOOL

Closed Loop Solar
Space and Water Heating System

Schematic

SCALE N.T.S.
PROJECT NO. 1425-81
DWG. NO. 1

"SYSTEM C"



NOTE COLLECTOR AREA IS 100m^2

DATE	MAY, 1982
DESIGNED	S.B
DRAWN	C.H
CHECKED	J.R

ACME ASSOCIATES
Engineers/Ingénieurs

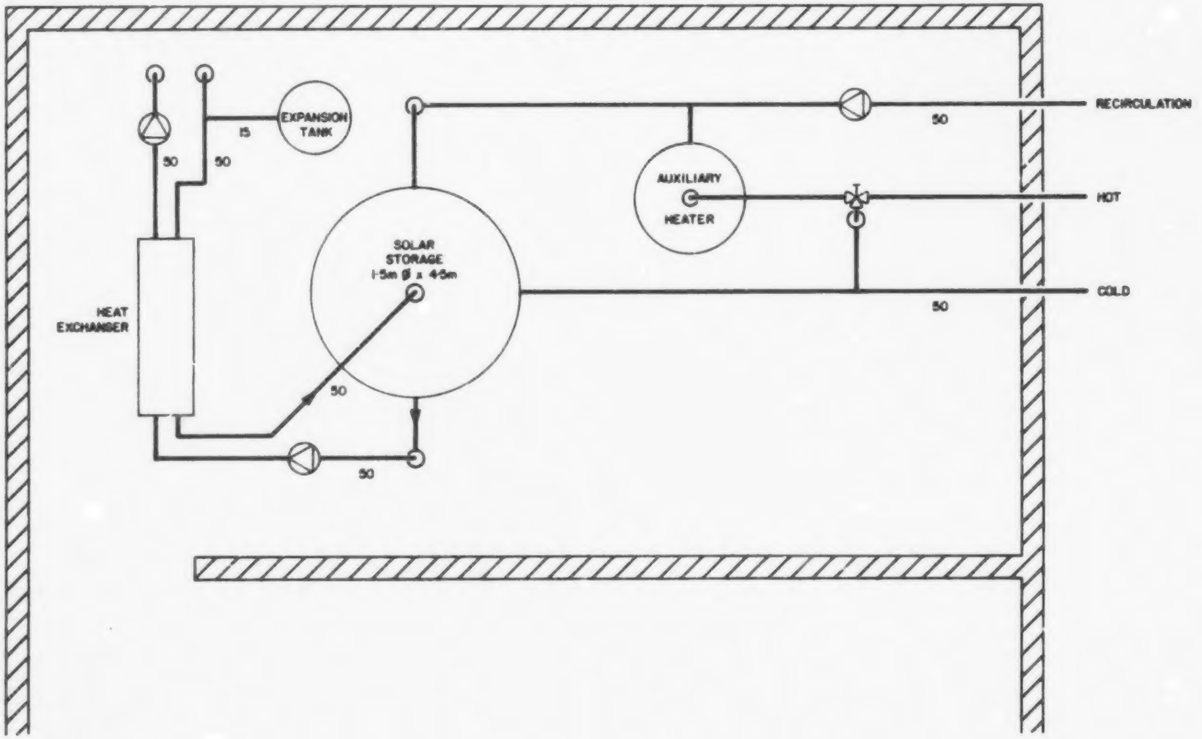
GRAYSTONES PUBLIC SCHOOL

Closed Loop Solar
Space and Water Heating System

COLLECTOR LAYOUT

SCALE	PROJECT NO.	DWG. NO.
N.T.S.	1425-81	2

"SYSTEM C"



DATE MAY, 1982
DESIGNED S.B
DRAWN C.H
CHECKED J.R

ACME ASSOCIATES
Engineers / Ingénieurs

GRAYSTONES PUBLIC SCHOOL

Closed Loop Solar
Space and Water Heating System

EQUIPMENT ROOM

SCALE N.T.S.
PROJECT NO 1425-81
DWG. NO 3

"SYSTEM C"

SELECTED INSTRUMENTATION

GRAYSTONES PUBLIC SCHOOL
CLOSED LOOP SOLAR SYSTEM - SPACE AND WATER HEATING

1. Sixteen Peterson Plugs, part number 110, to be installed in the specified locations in elbows.

2. Seven Platinum RTD (DIN 43760), Omega Part No. 44034, wire wound probes with accuracy of;

   plus or minus .3° C @ 0°C
   and plus or minus .6° C @ 100°C

   to be installed in temperature wells located in 90° elbows.

3. Digital temperature readouts; Omega Model 410B; ten point selector switch, four wire lead-resistance compensated standard platinum RTD (DIN 43760) with,

   range from 0°C - 100°C,
   resolution of .1°C,
   accuracy .1% of scale; plus or minus one digit,
   stability - 100 ppm/°C
   sampling time - 1 second.

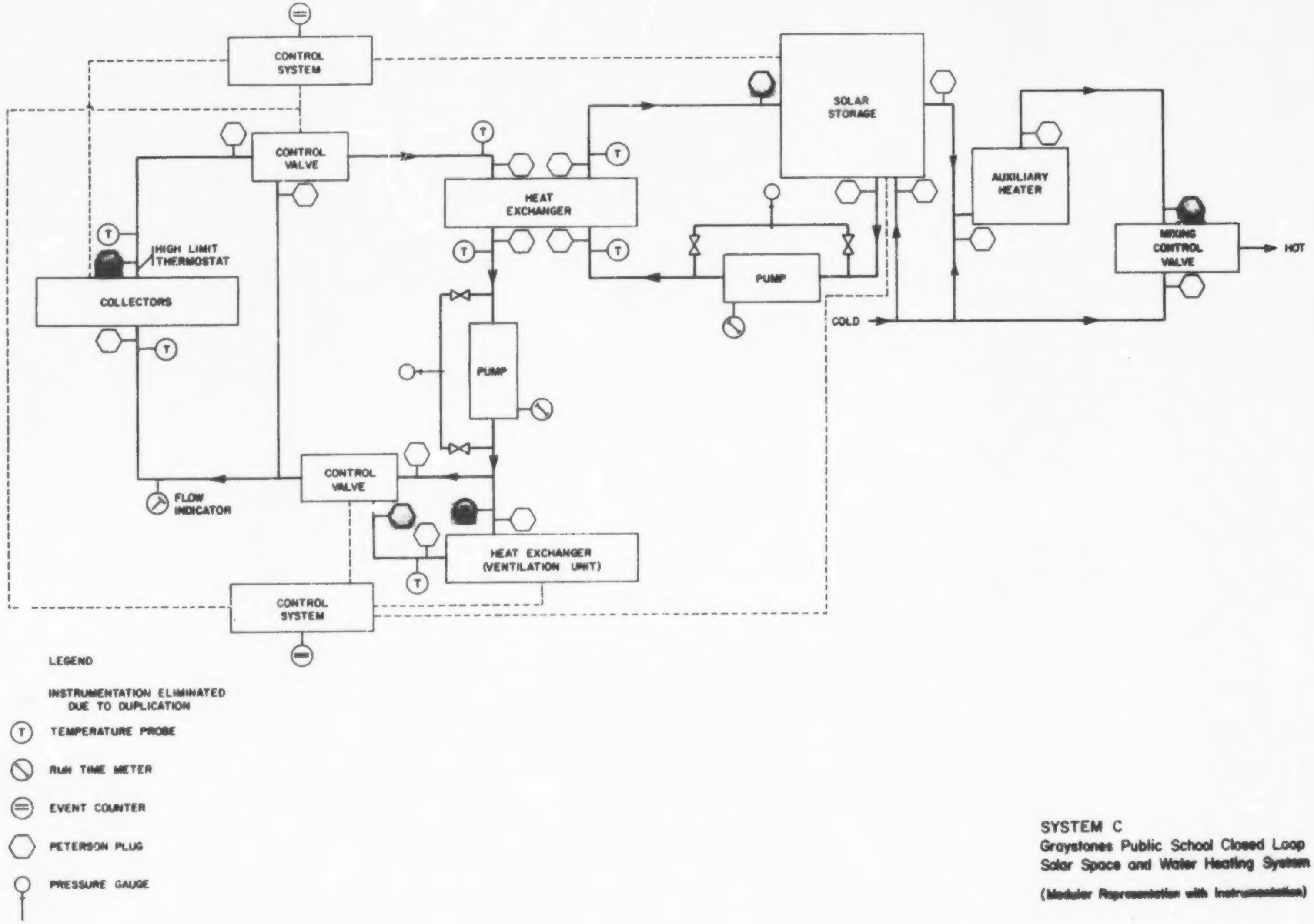
4. Two pressure gauges with a range from 0 to 600 kPa.

5. Two Bach Simpson Number 1357 ETIF run-time meters.

6. Two Hecom AO-040 event counters.

7. One flow indicator.

8. One high limit thermostat.



SYSTEM C
Graystones Public School Closed Loop
Solar Space and Water Heating System

(Modular Representation with Instrumentation)

START-UP PROCEDURES

GRAYSTONES PUBLIC SCHOOL
CLOSED LOOP SOLAR SYSTEM - SPACE AND WATER HEATING

INDEX

1. General Introduction to Start-Up Document

2. Site Inspection
    - Preparations
    - Collectors
    - Piping
    - Insulation
    - Thermal Storage
    - Electrical

3. Verification of Glycol Properties
    - Preparations
    - Responsibilities
    - Lab Tests
        - Test No. 1 - Reserve Alkalinity
        - Test No. 2 - Concentration Ratio
        - Test No. 3 - pH Level

4. Differential Controller Tests
    - Preparations
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    - Scheduling
    - Test No. 1 - Fail Safe Operation
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5. Motor and Pump Test
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    - Preparations - Pump
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    - Scheduling
    - Direction of Rotation
    - Motor - Amperage
    - Pump - Circulation Test

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7. Final Visual Inspection

8. Flow Balancing
    - Preliminary Information
    - Collector Loop Flow Rate
    - Collector Bank Flow Rates
    - Final Flow Adjustment

1. General Introduction to Start-Up Document

Start-up is a series of tests and inspections performed during and immediately after construction to ensure that the system and its components are installed correctly, and are capable of operating at specified levels.

The following tests are performed during and immediately following the construction phase of the project. Since component testing does not require the system to be in a completed and operational mode, the component tests may be done immediately following the installation of the component. In cases where various pre-conditions must be met in order to perform the test, testing should be done at the earliest possible date following the installation of these components. When the system has been fully constructed, a final visual inspection and system flow checks should be performed.

Supportive documentation must be prepared following each test or series of tests. This documentation will be maintained in a project file and summarized when the testing is complete. This documentation will help the owner in his final assessment of the system.

Testing may be done whenever components are made available for testing. It is not necessary to test them in the order the tests are described.

2. Site Inspection

Preparations

- obtain a copy of the design specifications, design drawings and shop drawings;
- obtain copies of the manufacturer's specifications for all major components in the system (collectors, pumps, heat exchangers, controllers, control valves);
- prepare an "inspection" checklist. This should be a specification sheet that details the components that should be installed. This sheet will be updated and dated following each inspection;
- the contractor should attach a sticker to pump timers indicating:
    - the date the system became fully operational,
    - the pump timer reading on that date.

Collectors

- verify that the number and type of collectors specified in the shop drawings have been installed;
- verify that the collectors have been installed in accordance with the designer's and manufacturer's recommendations;
- verify that the collectors are fed from the bottom and returned from the top;
- if any expansion couplings have been used in the array, ensure that adequate play is available for both full expansion and full contraction;

- check the security of all fasteners including those holding the collectors to the support structure, and those used in assembly of the support structure;
- ensure that load spreading washers have been used where necessary on collector attachment points;
- verify that flashings are firmly supported;
- ensure that there is a isolating gasket between any aluminum collectors and a steel frame.

Piping

- verify that all pipes, valves and fittings have been installed as specified;
- ensure that gate valves are used only for fully open or fully closed applications;
- verify that the pump is physically connected in the proper flow direction;
- verify that pumps have an adequate suction head;
- verify that the heat exchanger connections are made in the proper direction;
- verify that the expansion tank is on the suction side of the pump;
- verify that the pressure rating of the relief valve on the glycol loop is higher than the system pressure, but not higher than the rated pressure of the expansion tank;
- ensure that the collectors cannot be isolated from the expansion tank or pressure relief devices by closing valves;

- ensure that drain valves are located such that all piping can be drained;

- if a backflow preventor is used, verify that there is an expansion tank between it and the storage tank;

- since a backflow preventor may discharge fluid, verify that it is not installed near any electrical components which might be damaged;

- if the pump is a variable speed type, verify that it is set as recommended by the manufacturer;

- verify that there are sufficient pipe hangers, supports and expansion devices to compensate for thermal effects.

Insulation

- verify that the levels of insulation are as specified;

- verify that all insulation is:

    - securely fastened,
    - appropriately weatherproofed and protected from physical abuse,
    - protected from ultra-violet degradation (if applicable).

- verify that all test points are properly insulated;

- verify that any seams on piping jackets point downward to prevent moisture penetration;

- verify that there is insulation on the underside of storage tanks;

- verify that insulation does not impede the proper cooling of motors.

Thermal Storage

- verify that the storage tank is as specified or designed;
- verify that the pressure relief valves are installed and set to protect the system component with the lowest pressure rating;
- if a non-toxic fluid is specified, verify that a label is affixed in the vicinity of the fill valve, indicating that only non-toxic fluid be used.

Electrical

- verify that temperature sensors are firmly supported and protected from physical damage;
- ensure that all sensor wiring is protected from physical damage;
- verify that controls are located such that accidental adjustment is not possible;
- verify that wiring is installed according to local electrical codes;
- ensure that the instrumentation required for commissioning is available and properly installed.

3. Verification of Glycol Properties

Preparations

- the working fluid is tested to ensure that the mixture in the system will provide the required freeze protection, and that the fluid is of the proper type;

- the specified glycol properties:

  - type of antifreeze propylene glycol
  - concentration - 50 % antifreeze
    (by volume) - 50 % water
  - acidity - pH 7.9
  - reserve alkalinity, minimum 10

- the solution should have circulated for at least 30 minutes to assure that the sample is representative.

Responsibilities

- the contractor shall drain a small sample of the heat transfer fluid from the system for testing. The sample shall be sent to a lab for analysis and a copy of the test report sent to the owner or to his appointed representative.

Lab Tests

Test No. 1 - Reserve Alkalinity

- determine the amount of alkaline inhibitors present in the antifreeze solution by means of a reserve alkalinity test.

The test should be conducted in accordance with ASTM D 1121-72 Reserve Alkalinity of Engine Antifreeze, Antirusts and Coolants:

- check the specific antifreeze manufacturer for the desired reserve alkalinity and the method of restoring the solution to the required level;
- Example: Dow recommends adding dipotassium phosphate to the glycol solution if the reserve alkalinity falls below 9.0. The level should be maintained in the range of 10 to 12.

Reserve Alkalinity as measured in test __________

Test No. 2 - Concentration Ratio

- determine the antifreeze to water concentration of the solution:
  - the concentration may be obtained with a hydrometer, refractometer or by the ASTM E 203 - 75 - Water using Karl Fischer Reagent.

Concentration as measured in test - _________ % antifreeze
- _________ % water

Test No. 3 - pH Level

- determine the acidity of the solution in accordance with ASTM D 1613 - 66 (Reapproved 1972) - Acidity in volatile solvents and chemical intermediates used in paint, varnish, lacquer and related products.

pH level as measured in test _________

4. Control System Tests

Preparations

- obtain a copy of the temperature sensor characteristic curve from the manufacturer (resistance vs. temperature);

- obtain variable resistors which can be substituted for the system temperature sensors. These resistors can either have a built-in means of reading the set resistance or can be standard potentiometers from which the resistance can be determined using an accurate resistance meter. The variable resistors should have a range of 0 to 100,000 ohms;

- the controller should be wired for power.

Responsibilities

- the tests shall be the responsibility of the contractor;

- all testing will be witnessed by the owner or by his appointed representative and the design consultant.

Scheduling

- the tests will be performed following the installation of the controller and temperature sensors;

- the tests may be conducted at any level of solar insolation and system flow.

Test No. 1 - Fail Safe Operation

- switch off the electrical power to all pumps and/or control valves;

- verify that the controller is receiving electrical power;

- test the controller for short circuit protection (zero resistance). With a test light on the leads to the pump or to the control valve it operates, short circuit the temperature sensor leads. The test light should not come on;

- test the controller for open circuit protection (infinite resistance). With a test light on the leads to the pump or to the control valve it operates, open circuit the temperature sensor leads. The test light should not come on.

Test No. 2 - Differential Setting

Control No. 1

- switch off the electrical power to the control valve;

- set the differential controller for the recommended temperature differential;

	Collector	Solar Storage
Specified temperature differential	on 10 °C	on 90 °C
	off 3 °C	off 93 °C

- disconnect the collector sensor and the solar storage sensor at the controller and substitute with appropriate variable resistors with read outs;

- from the temperature sensor characteristic curve, determine the resistance associated with the specified on and off collector temperature limit:

  Resistance for 27°C (on) __________

  Resistance for 23°C (off) __________

- set the resistance of the solar storage input equal to 60°C and vary the collector resistance until an output is measured at the controller output terminal (to control valve):

  Measured resistance for "on" __________

- vary the resistance until an output is measured at the controller output terminal (to control valve):

  Measured resistance for "off" __________

- compare measured readings with expected reading:

  on: $\frac{\text{expected - measured}}{\text{expected}} \times 100\% =$ __________

  off: $\frac{\text{expected - measured}}{\text{expected}} \times 100\% =$ __________

- from temperature sensor characteristic curve, determine the resistance associated with the specified on and off solar storage temperature limits:

  Resistance for 90°C (on) __________

  Resistance for 93°C (off) __________

- set the resistance of the collector to 30°C and vary the solar storage resistance until an output is measured at the controller output terminal (to control valve):

  Measured resistance for "on" __________

Thermistor Resistance Versus Temperature

PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032
Ω@25°C	2252	3000	5000	10,000	30,000
BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE
END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED
TEMP. °C	RESISTANCE Ω				
+40	1200	1598	2663	5592	16.15K
41	1152	1535	2559	5389	15.52K
42	1107	1475	2459	5193	14.92K
43	1064	1418	2363	5006	14.35K
44	1023	1363	2272	4827	13.80K
45	983.8	1310	2184	4655	13.28K
46	946.2	1260	2101	4489	12.77K
47	910.2	1212	2021	4331	12.29K
48	875.8	1167	1944	4179	11.83K
49	842.8	1123	1871	4033	11.39K
+50	811.3	1081	1801	3893	10.97K
51	781.1	1040	1734	3758	10.57K
52	752.2	1002	1670	3629	10.18K
53	724.5	965.0	1608	3504	9807
54	697.9	929.6	1549	3385	9450
55	672.5	895.8	1493	3270	9109
56	648.1	863.3	1439	3160	8781
57	624.8	832.2	1387	3054	8467
58	602.4	802.3	1337	2952	8166
59	580.9	773.7	1290	2854	7876
+60	560.3	746.3	1244	2760	7599
61	540.5	719.9	1200	2669	7332
62	521.5	694.7	1158	2582	7076
63	503.3	670.4	1117	2497	6830
64	485.8	647.1	1079	2417	6594
65	469.0	624.7	1041	2339	6367
66	452.9	603.3	1006	2264	6149
67	437.4	582.6	971.1	2191	5940
68	422.5	562.8	938.0	2122	5738
69	408.2	543.7	906.3	2055	5545
+70	394.5	525.4	875.7	1990	5359
71	381.2	507.8	846.4	1928	5180
72	368.5	490.9	818.3	1868	5007
73	356.2	474.7	791.2	1810	4842
74	344.5	459.0	765.1	1754	4682
75	333.1	444.0	740.0	1700	4529
76	322.3	429.5	715.9	1648	4381
77	311.8	415.6	692.7	1598	4239
78	301.7	402.2	670.3	1549	4102
79	292.0	389.3	648.8	1503	3970
+80	282.7	376.9	628.1	1458	3843
81	273.7	364.9	608.2	1414	3720
82	265.0	353.4	588.9	1372	3602
83	256.7	342.2	570.4	1332	3489
84	248.6	331.5	552.6	1293	3379
85	240.9	321.2	535.4	1255	3273
86	233.4	311.3	518.8	1218	3172
87	226.2	301.7	502.8	1183	3073
88	219.3	292.4	487.4	1149	2979
89	212.6	283.5	472.6	1116	2887
+90	206.1	274.9	458.2	1084	2799
91	199.9	266.6	444.4	1053	2714
92	193.9	258.6	431.0	1023	2632
93	188.1	250.9	418.2	994.2	2552
94	182.5	243.4	405.7	966.3	2476
95	177.1	236.2	393.7	939.3	2402
96	171.9	229.3	382.1	913.2	2331
97	166.9	222.6	370.9	887.9	2262
98	162.0	216.1	360.1	863.4	2195
99	157.3	209.8	349.7	839.7	2131

PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032
Ω@25°C	2252	3000	5000	10,000	30,000
BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE
END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED
TEMP. °C	RESISTANCE Ω				
+100	152.8	203.8	339.6	816.8	2069
101	148.4	197.9	329.8	794.6	2009
102	144.2	192.2	320.4	773.1	1950
103	140.1	186.8	311.3	752.3	1894
104	136.1	181.5	302.5	732.1	1840
105	132.3	176.4	294.0	712.6	1788
106	128.6	171.4	285.7	693.6	1737
107	125.0	166.7	277.8	675.3	1688
108	121.6	162.0	270.1	657.5	1640
109	118.2	157.6	262.6	640.3	1594
+110	115.0	153.2	255.4	623.5	1550
111	111.8	149.0	248.4	607.3	1507
112	108.8	145.0	241.6	591.6	1465
113	105.8	141.1	235.1	576.4	1425
114	103.0	137.2	228.7	561.6	1386
115	100.2	133.6	222.6	547.3	1348
116	97.6	130.0	216.7	533.4	1311
117	95.0	126.5	210.9	519.9	1276
118	92.5	[illegible]	205.3	[illegible]	1241
119	[illegible]	119.9	199.9	[illegible]	[illegible]
+120	87.7	116.6	194.7	[illegible]	1176
121	85.4	113.8	189.6	469.8	1145
122	83.2	110.8	184.7	458.2	1114
123	71.1	107.9	179.9	446.9	1085
124	79.0	105.2	175.3	435.9	1057
125	77.0	102.5	170.8	425.3	1029
126	75.0	99.9	166.4	414.9	1002
127	73.1	97.3	162.2	404.9	976.3
128	71.3	94.9	158.1	395.1	951.1
129	69.5	92.5	154.1	385.6	926.7
+130	67.8	90.2	150.3	376.4	903.0
131	66.1	87.9	146.5	367.4	880.0
132	64.4	85.7	142.9	358.7	857.7
133	62.9	83.6	139.4	350.3	836.1
134	61.3	81.6	136.0	342.0	815.0
135	59.8	79.6	132.6	334.0	794.6
136	58.4	77.6	129.4	326.3	774.8
137	57.0	75.8	126.3	318.7	755.6
138	55.6	73.9	123.2	311.3	736.9
139	54.3	72.2	120.3	304.2	718.8
+140	53.0	70.4	117.4	297.2	701.2
141	51.7	68.8	114.6	290.4	684.1
142	50.5	67.1	111.9	283.8	667.5
143	49.3	65.5	109.2	277.4	651.3
144	48.2	64.0	106.7	271.2	635.5
145	47.0	62.5	104.2	265.1	620.3
146	45.9	61.1	101.8	259.2	605.5
147	44.9	59.6	99.40	253.4	591.1
148	43.8	58.3	97.10	247.8	577.1
149	42.8	56.9	94.87	242.3	563.5
+150	41.9	55.6	92.70	237.0	550.2

Note: Data in black refer to thermistors with ±0.2°C interchangeability. Data in blue refer to thermistors with ±0.1°C interchangeability. Temperature resistance figures are the same for both types.

Note: [illegible] with ±0.2°C interchangeability [illegible] uncased [illegible] See Part [illegible] thermistors [illegible] ±0.2°C interchangeable thermistors. Example [illegible] thermistor, 44035 [illegible] thermistor [illegible] values.

Thermistor Resistance versus Temperature

PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032
Ω@25°C	2252	3000	5000	10.000	30.000
BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE
END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED
TEMP. °C	RESISTANCE Ω				
—80	1660K	2211K	3685K	3558K	
79	1518K	2022K	3371K	3296K	
78	1390K	1851K	3086K	3055K	
77	1273K	1696K	2827K	2833K	
76	1167K	1555K	2592K	2629K	
75	1071K	1426K	2378K	2440K	
74	982.8K	1309K	2182K	2266K	
73	902.7K	1202K	2005K	2106K	
72	829.7K	1105K	1843K	1957K	
71	763.1K	1016K	1695K	1821K	
—70	702.3K	935.4K	1560K	1694K	
69	646.7K	861.4K	1436K	1577K	
68	595.9K	793.7K	1323K	1469K	
67	549.4K	731.8K	1220K	1369K	
66	506.9K	675.2K	1126K	1276K	
65	467.9K	623.3K	1039K	1190K	
64	432.2K	575.7K	959.9K	1111K	
63	399.5K	532.1K	887.2K	1037K	
62	369.4K	492.1K	820.5K	968.4K	
61	341.8K	455.3K	759.2K	904.9K	
—60	316.5K	421.5K	702.9K	845.9K	
59	293.2K	390.5K	651.1K	791.1K	
58	271.7K	361.9K	603.5K	740.2K	
57	252.0K	335.7K	559.7K	692.8K	
56	233.8K	311.5K	519.4K	648.8K	
55	217.1K	289.2K	482.2K	607.8K	
54	201.7K	268.6K	447.9K	569.6K	
53	187.4K	249.7K	416.3K	534.1K	
52	174.3K	232.2K	387.1K	501.0K	
51	162.2K	216.0K	360.2K	470.1K	
—50	151.0K	201.1K	335.3K	441.3K	
49	140.6K	187.3K	312.3K	414.5K	
48	131.0K	174.5K	291.0K	389.4K	
47	122.1K	162.7K	271.3K	366.0K	
46	113.9K	151.7K	253.0K	344.1K	
45	106.3K	141.6K	236.2K	323.7K	
44	99.26K	132.2K	220.5K	304.6K	
43	92.72K	123.5K	205.9K	286.7K	
42	86.65K	115.4K	192.5K	270.0K	
41	81.02K	107.9K	180.0K	254.4K	
—40	75.79K	101.0K	168.3K	239.8K	884.6K
39	70.93K	94.48K	157.5K	226.0K	830.9K
38	66.41K	88.46K	147.5K	213.2K	780.8K
37	62.21K	82.87K	138.2K	201.1K	733.9K
36	58.30K	77.66K	129.5K	189.8K	690.2K
35	54.66K	72.81K	121.4K	179.2K	649.3K
34	51.27K	68.30K	113.9K	169.3K	611.0K
33	48.11K	64.09K	106.9K	160.0K	575.2K
32	45.17K	60.17K	100.3K	151.2K	541.7K
31	42.42K	56.51K	94.22K	143.0K	510.4K
—30	39.86K	53.10K	88.53K	135.2K	481.0K
29	37.47K	49.91K	83.22K	127.9K	453.5K
28	35.24K	46.94K	78.26K	121.1K	427.7K
27	33.15K	44.16K	73.62K	114.6K	403.5K
26	31.20K	41.56K	69.29K	108.6K	380.9K
25	29.38K	39.13K	65.24K	102.9K	359.6K
24	27.67K	36.86K	61.45K	97.49K	339.6K
23	26.07K	34.73K	57.90K	92.43K	320.9K
22	24.58K	32.74K	54.58K	87.68K	303.3K
21	23.16K	30.87K	51.47K	83.16K	286.7K

PART NO.	44004 44033	44005 44030	44007 44034	44006 44031	44008 44032
Ω@25°C	2252	3000	5000	10.000	30.000
BODY	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE	BLACK ORANGE
END	YELLOW ORANGE	GREEN BLACK	VIOLET YELLOW	BLUE BROWN	GRAY RED
TEMP. °C			RESISTANCE Ω		
—20	21.87K	29.13K	48.56K	78.91K	271.2K
19	20.64K	27.49K	45.83K	74.91K	256.5K
18	19.48K	25.95K	43.27K	71.13K	242.8K
17	18.40K	24.51K	40.86K	67.57K	229.8K
16	17.39K	23.16K	38.61K	64.20K	217.6K
15	16.43K	21.89K	36.49K	61.02K	206.2K
14	15.54K	20.70K	34.50K	58.01K	195.4K
13	14.70K	19.58K	32.63K	55.17K	185.2K
12	13.91K	18.52K	30.88K	52.48K	175.6K
11	13.16K	17.53K	29.23K	49.94K	166.6K
—10	12.46K	16.60K	27.67K	47.54K	158.0K
9	11.81K	15.72K	26.21K	45.27K	150.0K
8	11.19K	14.90K	24.83K	43.11K	142.4K
7	10.60K	14.12K	23.54K	41.07K	135.2K
6	10.05K	13.39K	22.32K	39.14K	128.5K
5	9534	12.70K	21.17K	37.31K	122.1K
4	9046	12.05K	20.08K	35.57K	116.0K
3	8586	11.44K	19.06K	33.93K	110.3K
2	8151	10.86K	18.10K	32.37K	104.9K
— 1	7741	10.31K	17.19K	30.89K	99.80K
0	7355	9796	16.33K	29.49K	94.98K
+ 1	6989	9310	15.52K	28.15K	90.41K
2	6644	8851	14.75K	26.89K	86.09K
3	6319	8417	14.03K	25.69K	81.99K
4	6011	8006	13.34K	24.55K	78.11K
5	5719	7618	12.70K	23.46K	74.44K
6	5444	7252	12.09K	22.43K	70.96K
7	5183	6905	11.51K	21.45K	67.66K
8	4937	6576	10.96K	20.52K	64.53K
9	4703	6265	10.44K	19.63K	61.56K
+10	4482	5971	9951	18.79K	58.75K
11	4273	5692	9486	17.98K	56.07K
12	4074	5427	9046	17.22K	53.54K
13	3886	5177	8628	16.49K	51.13K
14	3708	4939	8232	15.79K	48.84K
15	3539	4714	7857	15.13K	46.67K
16	3378	4500	7500	14.50K	44.60K
17	3226	4297	7162	13.90K	42.64K
18	3081	4105	6841	13.33K	40.77K
19	2944	3922	6536	12.79K	38.99K
+20	2814	3748	6247	12.26K	37.30K
21	2690	3583	5972	11.77K	35.70K
22	2572	3426	5710	11.29K	34.17K
23	2460	3277	5462	10.84K	32.71K
24	2354	3135	5225	10.41K	31.32K
25	2252	3000	5000	10.00K	30.00K
26	2156	2872	4787	9605	28.74K
27	2064	2750	4583	9227	27.54K
28	1977	2633	4389	8867	26.40K
29	1894	2523	4204	8523	25.31K
+30	1815	2417	4029	8194	24.27K
31	1739	2317	3861	7880	23.28K
32	1667	2221	3702	7579	22.33K
33	1599	2130	3549	7291	21.43K
34	1533	2042	3404	7016	20.57K
35	1471	1959	3266	6752	19.74K
36	1412	1880	3134	6500	18.96K
37	1355	1805	3008	6258	18.21K
38	1301	1733	2888	6026	17.49K
+39	1249	1664	2773	5805	16.80K

- vary the resistance until there is no output measured at the controller output terminal (to control valve):

Measured resistance for "off" __________

- compare measured readings with expected readings:

on: $\frac{\text{expected - measured}}{\text{expected}} \times 100\% =$ __________

off: $\frac{\text{expected - measured}}{\text{expected}} \times 100\% =$ __________

- if the two figures disagree substantially (more than ten percent), adjust the controller setting and repeat the above.

Control No. 2

- switch off the electrical power to the control valve;

- set the controller for the following cases:

SOLAR SYSTEM "ON"?	SOLAR WATER TEMPERATURE	AIR TEMPERATURE	REQUIRED ACTION	VALVE TWO POSITION
yes	and	20°C	Discontinue heating air with system	Open "A", "B" Close "C"
yes	and	16°C	Begin heating air with solar system	Open "A", "B", and "C"
no	and 38°C and	16°C	Begin heating air with stored heat in solar tank	Open "A", "C" Close "B"
no	and 35°C or	20°C	Discontinue heating air with stored heat in solar tank	Open "A", "B" Close "C"

- disconnect the solar system on/off sensor, the solar water temperature sensor and the air temperature sensor at the controller. Substitute with appropriate variable resistors with read outs;

- from the temperature sensor characteristic curve, determine the resistance associated with the specified on and off air temperature limits:

  Resistance for 16°C (on) __________

  Resistance for 20°C (off) __________

- set the resistance of the solar system on/off input equal to "on" and vary the air temperature resistor until the output "A", "B", "C" open is obtained:

  Measured resistance for "on" __________

- vary the air temperature resistor until the output "A", "B" open, "C" closed is obtained:

  Measured resistance for "off" __________

- compare measured readings with expected readings:

  on: $\frac{\text{expected - measured}}{\text{expected}} \times 100\% =$ __________

  off: $\frac{\text{expected - measured}}{\text{expected}} \times 100\% =$ __________

- if the two figures disagree substantially (more than ten percent), adjust the controller setting and repeat the above test;

- from the temperature sensor characteristic curve, determine the resistance associated with the specified "on" and "off" solar water temperature for heating the air when the solar system is off:

  Resistance for 38°C (on) ___________

  Resistance for 35°C (off) ___________

- set the resistance of the solar system on/off input equal to "on", the resistance of the solar water temperature equal to 0 °C, and vary the air temperature resistor until the output "A", "B", "C" open is obtained. Then, switch the solar system resistance to "off" and vary the solar water temperature resistance until "A" and "C" are open and "B" is closed.

  Measured resistance for "on" ___________

- vary the solar water temperature resistance until "A" and "B" are open and "C" is closed:

  Measured resistance for "off" ___________

- compare measured readings with expected readings:

  on: $\frac{\text{expected - measured}}{\text{expected}} \times 100\% =$ ___________

  off: $\frac{\text{expected - measured}}{\text{expected}} \times 100\% =$ ___________

- if these two figures disagree substantially (more than ten percent), adjust the controller setting and repeat the above test.

5. Motor and Pump Test

Preparations - Motor

- single phase motors need not be checked; however, all three phase motors should be checked for proper direction of rotation;

- verify that the motor is fully wired, protected, and ready to operate.

Preparations - Pump

- assure that all valves are in the position required for normal system operation;

- collect the applicable pump curves.

Responsibilities

- the test shall be the responsibility of the contractor;

- all testing will be witnessed by the owner or his appointed representative and by the design consultant.

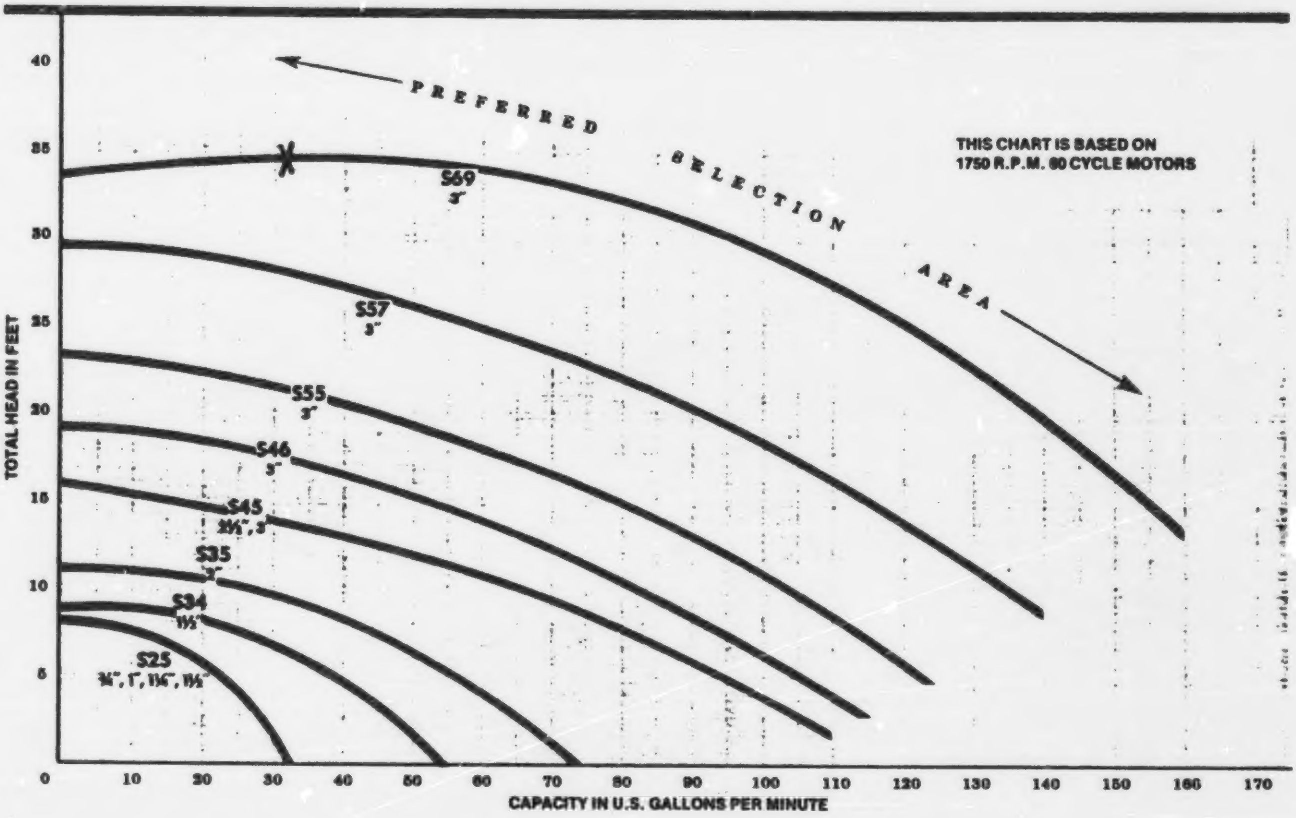
Scheduling

- the rotation test will be performed following the installation and wiring of the motor and the pump.

- perform the circulation test as soon as the system is filled with liquid.

GRAYSTONES PUBLIC SCHOOL
PUMP CURVE
FOR PRIMARY PUMP

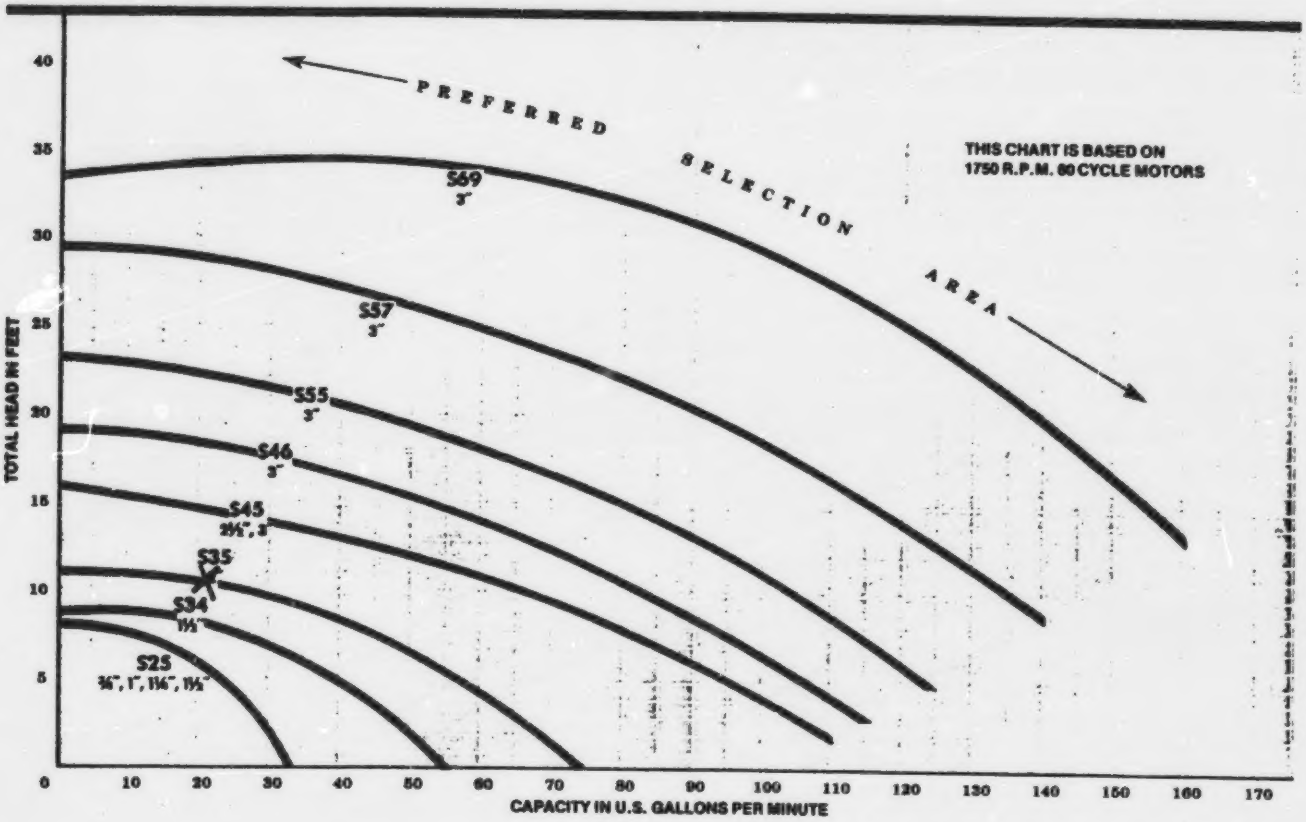
PERFORMANCE CURVES FOR PUMP SELECTION



X = operating point

GRAYSTONES PUBLIC SCHOOL
PUMP CURVE
FOR SECONDARY PUMP

PERFORMANCE CURVES FOR PUMP SELECTION



X = operating point

Direction of Rotation

- with the motor running, observe the end of the pump shaft to verify that it is running in the proper direction;

- if the pump is running backwards, connect the wires in the correct phase sequence.

Motor - Amperage

- with the motor operating, measure the current:

  Measured current ____________________

- the current should not exceed eighty percent of the nameplate rating.

Pump - Circulation Test

For each pump in the solar system, repeat this procedure:

- close the pump outlet valve;
- observe the pressures P_{in} and P_{out}. The pressure difference across the pump (P_{out} - P_{in}) should be the maximum operating pressure for the pump, as specified by the manufacturer, or the zero flow rate pressure from the pump curve.

Pump No. __1__ P_{in} ______ kPa
Outlet valve closed P_{out} ______ kPa
$P_{out} - P_{in}$ ______ kPa

- slowly, open the pump outlet valve;
- observe the output operating pressure P_{out}. The pump's output pressure should drop and remain at a pressure below the pump's stagnation pressure (P_{out} outlet valve closed). A drop in pressure and then a rise back to the stagnation pressure indicates a blockage in the system.

Outlet valve open P_{out} ______ kPa

Pump No. __2__ P_{in} ______ kPa
Outlet valve closed P_{out} ______ kPa
$P_{out} - P_{in}$ ______ kPa

Outlet valve open P_{out} ______ kPa

6. Leak Test

- the system should be pressure tested with the working fluid if possible;

- if conditions do not allow the use of the working fluid, an air or dry nitrogen test may be used;

- every liquid loop system shall hold for fifteen minutes;

  (a) without leakage, a water (glycol) pressure at least equal to the maximum pressure to which it may be subjected in service, or

  (b) without a drop in pressure, an air pressure of not less than 700 kPa or the maximum working pressure of the lowest rated component;

- all leaks should be noted and repaired immediately;

- the system should be retested following any repairs to the system.

7. Final Visual Inspection

- check the collector for outgassing:
    - in many instances, condensation forms on the underside of the glazing; however, this should "bake" off after one or two sunny days;
- if the condensation fails to bake off, then the condensation could be the by-product of the gases given off by the collector. In this case, the inside of the collector glazing will have to be cleaned or the glazing will have to be replaced;
- if condensation has fallen onto the absorber surface, an iridescent effect may appear. This will not effect the collector's performance if it is merely the condensate of water; however, if it is from outgassing, the oil residue will have to be removed from the absorber surface to restore the collector's performance. Before attempting to clean the absorber surface, contact the manufacturer of the collector for advice;
- verify that the system is completely filled with fluid. This check can be carried out by manually venting the air bleed valve at the high point in the system to ensure that no air is present;
- with the pump operating, verify the system flow by observing the flow indicator on the collector loop;
- verify that the system static pressure is within the tolerances of the given design and that this pressure does not exceed the rated pressure of the expansion tank;

Specified static pressure: primary loop: 100 kPa minimum
120 kPa maximum
secondary loop: 280 kPa minimum
400 kPa maximum

- verify that all manually operated valves are in the specified position (open or closed) required for normal operation of the system and that they have tags indicating the specified position;

- verify that the heat transfer fluid fill valve is sealed with a dated crimped seal.

8. System Flow Checks

Preliminary Information

- total collector loop flow required: 120 L/min
- obtain a copy of the manufacturer's pump curve for all pumps;

Collector Loop Flow Rate

- make sure the system is in an operating mode, with either the:
  - controller in the automatic position on a sunny day,
    or
  - controller in the manual position on an overcast day.
- if the collector loop has more than one pump for use during normal operation, make sure all the pumps are operating;
- check the flow indicator to verify that there is flow and that it is in the prescribed direction;
- the following test should be carried out for the pump in the collector loop;
  - measure the pressure differential across the pump;

    Measured pressure differential __________ kPa

  - from the manufacturer's pump curve, determine the operating point for the pump;
  - for this operating point, read off the operating flow rate;

    Flow rate as determined from pump curve __________ L/min

- adjust the flow by the means provided in the system until the flow rate is approximately equal to the specified flow rate;

- record the final operating flow rate:

Final operating flow rate ________ L/min

Collector Bank Flow Verification

- on a sunny day, with the circulation system operating and all balancing valves open, verify that flow exists in all banks. This may be accomplished by observing and recording the collector supply temperature and the bank outlet temperature for each bank of collectors:

collector supply temperature ________ °C
bank number __1__ outlet temperature ________ °C
__2__ ________ °C

- if any of the bank outlet temperatures are significantly different from any others, there may be a restriction in the circuit.

COMMISSIONING PROCEDURES

GRAYSTONES PUBLIC SCHOOL
CLOSED LOOP SOLAR SYSTEM - SPACE AND WATER HEATING

INDEX

1. General Introduction to Commissioning Document
    - Pre-conditions
    - Responsibilities
    - Scheduling

2. Verification of Pump Performance and System Flow Rates
    - Collector Loop Flow Rate
    - Bank Flow Rates

3. Final Flow Adjustment

4. Heat Exchanger Effectiveness

5. Preliminary Thermal Performance Test

1. General Introduction to Commissioning Document

Commissioning is a demonstration by the consultant and the contractor to the owner that the solar system is operating in a safe and efficient manner. The solar system will undergo a series of tests and adjustments to meet or exceed a prescribed level of efficiency.

Pre-conditions

- it is assumed that start-up has been successfully completed;

Responsibilities

- the commissioning will be carried out by the consultant and the contractor in the presence of the owner or his representative.

Scheduling

- the system must have been in operation for a minimum of five days after the final start-up test before the system is commissioned.

2. Verification of Pump Performance and System Flow Rates

Collector Loop Flow Rate

- make sure the system is in an operating mode, with either the:
  - controller in the automatic position on a sunny day,
    or
  - controller in the manual position on an overcast day.
- check the flow indicator to verify that there is flow and that it is in the prescribed direction;
- the following test should be carried out for the pump in the collector loop:
  - measure the operating amperage of the pump with a clamp-on ammeter;

    Measured amperage __________
  - convert amperage to the equivalent horsepower; using the following equation;

    Calculated horsepower __________

$$P = \sqrt{3}\,E\,I\cos\varphi \qquad \text{(three phase)}$$

where:

I = line current, amps
P = power, kW
E = line voltage, volts
$\cos\varphi$ = power factor

	Power Factor, $\cos \varphi$ three phase
1/2 HP or less	.75
1 - 2 HP	.75
2 1/2 - 15 HP	.80

1 HP = .7457 kW

- measure the pressure differential across the pump;

Measured pressure differential _________ kPa

- from the manufacturer's pump curve, determine the operating point for the pump;

- for this operating point, read off the operating flow rate;

Flow rate as determined from pump curve _________ L/min

- if the flow rate is not within twenty percent (plus or minus) of the specified flow rate, adjust the flow by the means provided in the system until the flow rate is within the allowable range, and record the new flow settings;

Final operating flow rate _________ L/min

Bank Flow Rates

- with the system operating, measure the temperature rise across each collector bank;

bank number __1__ temperature rise __________°C
__2__ __________°C

- if the temperature rise across the hottest bank is less than fifty percent greater than the temperature rise across the coldest bank, or within 1°C, and place a dated locking tag on all throttling valves;

- if the temperature rises are not within these limits, carry out the balancing procedures outlined below:

Balancing Procedures

- leave the balancing valve of the bank registering the highest temperature fully open - reduce the flow through the other banks by partially and judiciously closing the other balancing valves;

- leave the system to stabilize for about ten minutes and observe the bank outlet temperatures;

- repeat this process until the temperature rise across the hottest bank is less than fifty percent greater than the temperature rise across the coldest bank, or within 1°C, and place a dated locking tag on all throttling valves.

3. Final Flow Adjustment

- with the collector flows balanced, a final adjustment of the overall flow rate is made and the value is recorded;
- place a dated locking tag on the system throttling valve;

Note: A final flow adjustment is mandatory whenever the collector bank flows are altered.

Record the following:

Test Date: Time: Hours:

Total Collector Loop Flow ______________ L/min

bank number __1__ temperature rise __________ °C

__2__ __________ °C

4. Heat Exchanger Effectiveness

- the test should be carried out using the normal hot water draw on the load side;

- the design hot water draw rate is __80__ L/min;

- record the hot water draw rate during the test, if possible: ______ L/min

- with the pumps operating, measure and record the following temperatures: (Note the schematic of the heat exchanger on the following page which indicates where to measure the required temperatures.)

$T_{P(in)}$ - primary side inlet _____ °C

$T_{P(out)}$ - primary side outlet _____ °C

$T_{S(in)}$ - secondary side inlet _____ °C

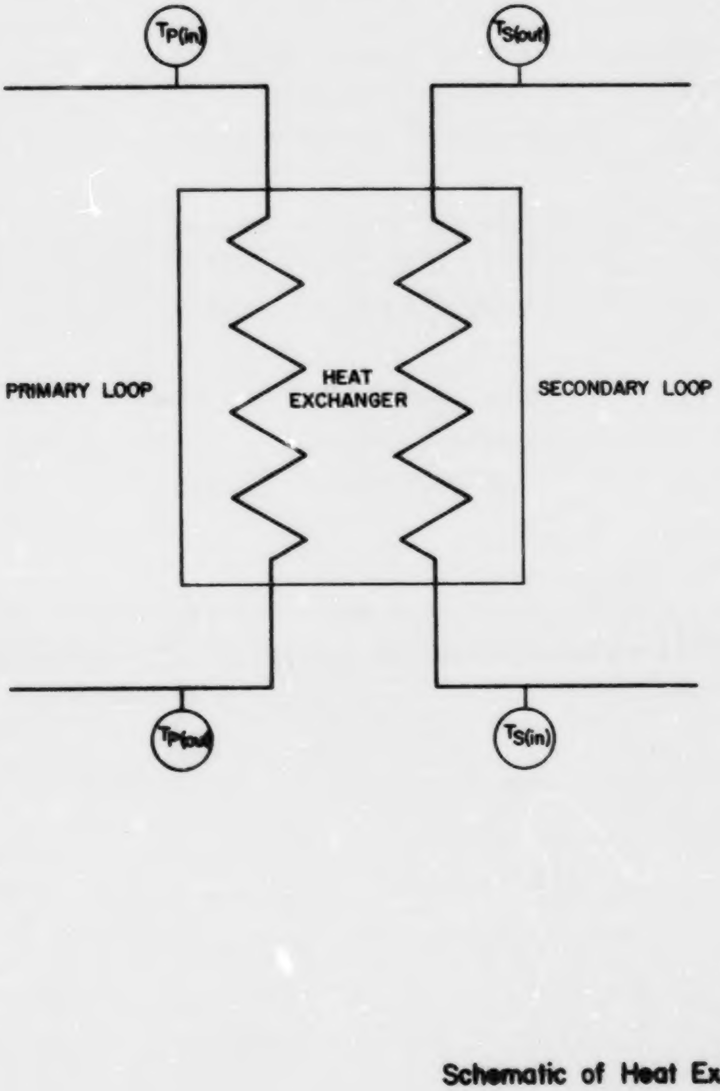
$T_{S(out)}$ - secondary side outlet _____ °C

- calculate the heat exchanger effectiveness (E) using the following equation: (Note: counter flow heat exchanger, minimum heat capacity rate on the secondary side)

$$E = \frac{T_{S(out)} - T_{S(in)}}{T_{P(in)} - T_{S(in)}}$$

Heat exchanger effectiveness ____________

A problem is indicated if the effectiveness is not within the following range: __.7__, __.85__.



Schematic of Heat Exchanger

5. Preliminary Thermal Performance Test

The preliminary thermal performance test is undertaken in order to assess the operation of the solar system as a whole, and to compare the results with the performance that should be expected based on the collector manufacturer's claimed performance.

Perform the thermal performance test on a sunny day between 11:00 a.m. and 1:00 p.m. The storage temperature must be well below the maximum.

- Record the following measurements:

T_A - outdoor ambient temperature ________°C

$T_{C(out)}$ - collector return temperature ________°C

$T_{C(in)}$ - collector supply temperature ________°C

F_S - total collector loop flow rate ________L/min

I - solar insolation ________W/m^2*

* The solar insolation should be measured using a hand held pyranometer. Measure the insolation during the test period. Hold the pyranometer against the surface of the collector when taking measurements.

Airport weather stations may be able to supply current solar insolation levels.

- determine the density and the specific heat of the collector heat transfer fluid:

where: c_p is the specific heat in J/kg^oC

$$= \frac{\% \text{ water} \times 1 \text{ kg/L} + \% \text{ glycol} \times c_p \text{ glycol}}{100} = \_\_\_\_\_\_\_ \text{ kg/L}$$

$$= \frac{\% \text{ water} \times 4190 \text{ J/kg}^oC \times \% \text{ glycol} \times c_p \text{ glycol}}{100} = \_\_\_\_\_\_\_ \text{ J/kg}^oC$$

- calculate the temperature rise across the collector:

$$T = T_{C(out)} - T_{C(in)} = \_\_\_\_\_\_\_ {}^oC$$

- determine the heat gain:

where: ρ is the density in kg/L

$$Q = \frac{F_S \times \rho \times T \times c_p}{60} = \_\_\_\_\_\_\_ W$$

$$\frac{L}{min} \times \frac{kg}{L} \times \frac{min}{s} \times {}^oC \times \frac{J}{kg\ {}^oC} \times \frac{W}{J/s}$$

- determine the heat gain per unit of collector area:

$q = Q/A$

$= \_\_\_\_\_\_\_\_\_ W/m^2$

- the efficiency is then:

$$\frac{q}{T} \times 100 = \_\_\_\_\_\_\_\_\%$$

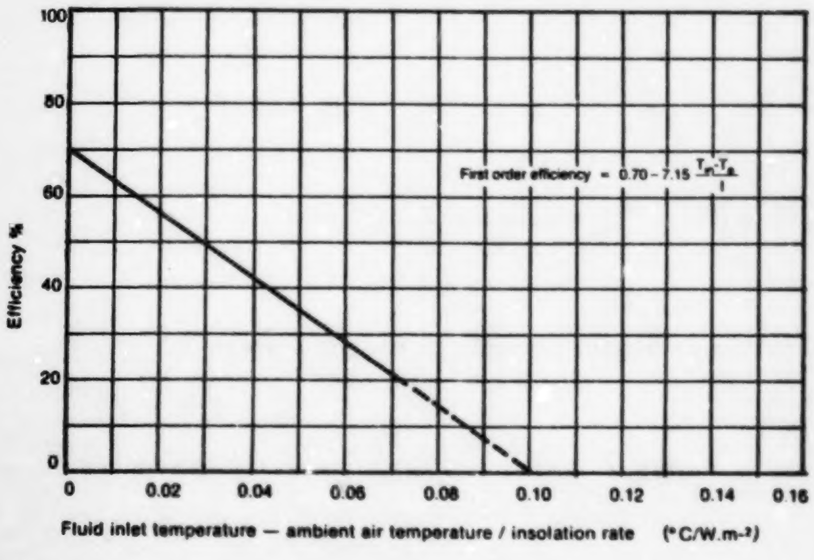
- determine the manufacturer's claimed efficiency, for the given conditions, for:

$$\text{Operating point} = \frac{T_{C(in)} - T_A}{I} \qquad \text{(parallel operation)}$$

- read the efficiency from the manufacturer's performance curve for this operating point.

Since the measured efficiency includes line losses, it can be expected to be slightly lower than the claimed efficiency for the collectors alone. However, the measured efficiency should not be more than twenty percent lower than the predicted value.

Collector Efficiency Curve



OPERATIONAL MONITORING DOCUMENT

GRAYSTONES PUBLIC SCHOOL
CLOSED LOOP SOLAR SYSTEM - SPACE AND WATER HEATING

INDEX

1. General System Description

2. System Operation

3. Introduction to Operational Monitoring

4. Operational Monitoring Procedures
    - Daily Operational Checklist
        - Pumps
        - System Pressures
        - System Temperatures
        - General Overview
    - Monthly Operational Schedule
    - Semi-Annual Operational Maintenance Schedule
        - Fluid Quality
        - Heat Exchanger Effectiveness
        - Sensor Calibration Check
        - Preventative Maintenance

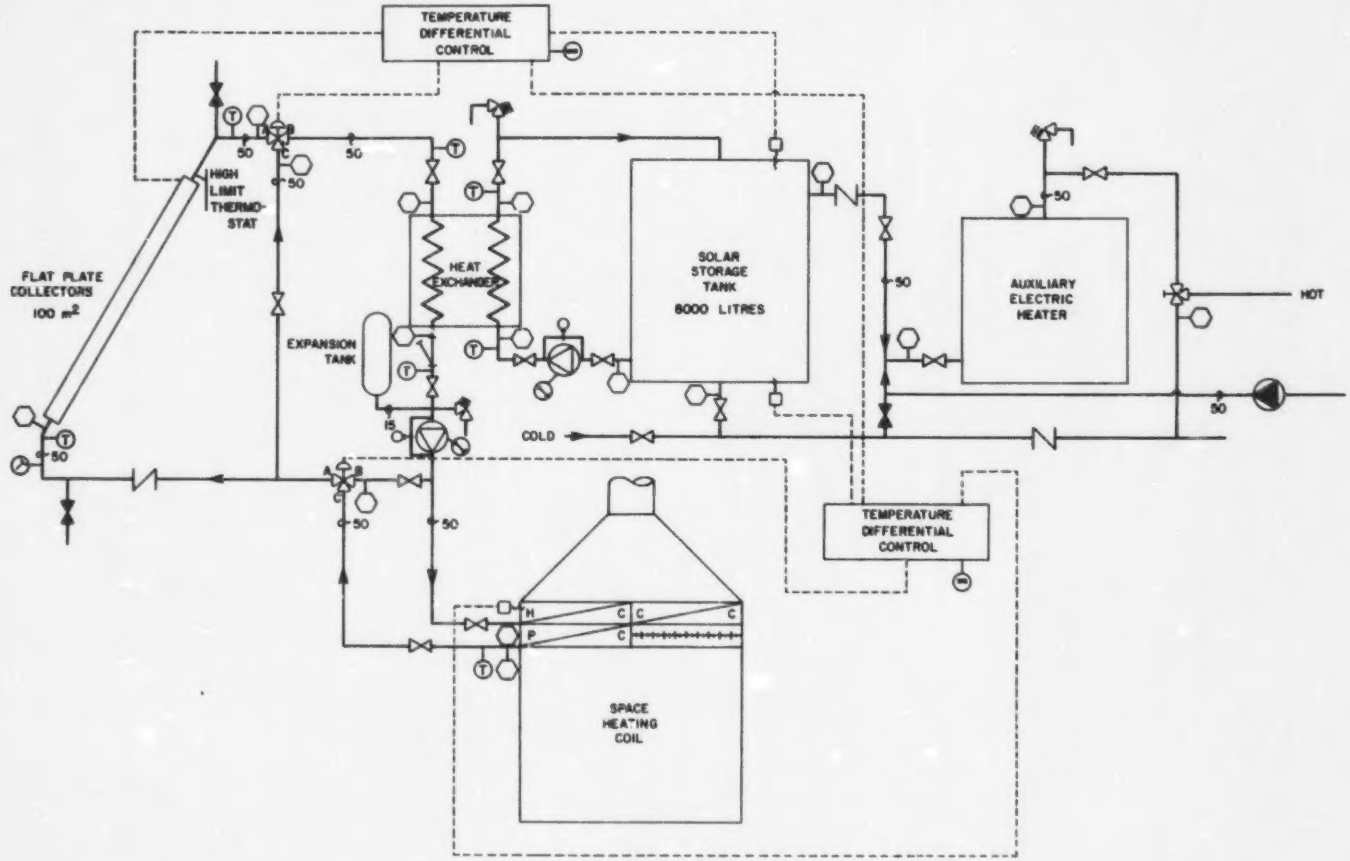
1. General System Description

This solar system is designed to heat 80 litres of water per minute and aid in the the space heating of the school. Previously, all water and air was heated electrically. The solar system will decrease the electric heating cost by approximately fifty percent.

Note the schematic of the solar system. The system is made up of two major loops; the primary loop and the secondary loop.

The primary loop is a closed loop of piping containing glycol. The primary loop pump circulates the glycol through the collectors, where it is heated, and then through the heat exchanger, where the heat from the glycol is transferred to the water in the secondary loop. If space heating is required, the primary loop is extended by opening a valve to circulate the heated glycol through the ventilation unit. An expansion tank and pressure relief valve are in the primary loop to allow for expansion of the glycol, if the temperature rises dramatically. A gate valve and strainer are upstream from the pump, and a gate valve is downstream. The gate valves are needed to isolate the pump from the rest of the system, if required. Two gate valves, one at the top of the loop, and the other at the bottom, are used to drain the glycol or to bleed off air. Their normal position is closed. There are two threeway valves in the primary loop. The first is a two-position three-way valve. For normal operation "A" and "B" will be open to allow the glycol to flow from the collectors to the heat exchanger. When no solar energy is available and the temperature of the water is sufficiently hot in the solar storage tank and space heating is required, "A" and "C" will be opened causing the collectors to be isolated from the primary loop. The heat from the solar storage tank will be transferred to the primary loop (to the ventilation unit) through the heat exchanger.

The second is a three-way modulating valve. If no space heating is required, "C" is closed to isolate the ventilation unit from the primary loop. If space heating is required, "B" and "C" control the amount of flow going to the ventilation unit. The secondary loop contains the water that is being heated. Cold water flows into the solar storage tank (flow is controlled by a gate


TEMPERATURE DIFFERENTIAL CONTROL
FLAT PLATE COLLECTORS 100 m²
HIGH LIMIT THERMOSTAT
50
HEAT EXCHANGER
EXPANSION TANK
15
SOLAR STORAGE TANK 8000 LITRES
AUXILIARY ELECTRIC HEATER
HOT
COLD
A
B
C
H
P
SPACE HEATING COIL
TEMPERATURE DIFFERENTIAL CONTROL

LEGEND

⊖	EVENT COUNTER	Ⓣ	TEMPERATURE PROBE
⊘	RUN TIME METER	⬡	PETERSON PLUG
⊘	FLOW METER	♀	PRESSURE GAUGE

DATE	MAY, 1982
DESIGNED	S.B.
DRAWN	C.H.
CHECKED	J.R.

ACME ASSOCIATES
Engineers/Ingénieurs

GRAYSTONES PUBLIC SCHOOL

Closed Loop Solar
Space and Water Heating System

Schematic with Instrumentation

SCALE	PROJECT NO.	DWG. NO.	REV.
N.T.S.	1425-81	4	

"SYSTEM C"

valve). It is them pumped (again, the pump can be isolated by two gate valves) from the storage tank through the heat exchanger, where it is heated by the glycol from the primary loop. It flows back into the solar storage tank. Note the pressure relief valve.

Hot water from the solar storage tank flows into the original electric heating tank along with recirculated hot water coming back from the cafeteria and recreation centre. A check valve prevents backflow into the solar energy storage tank and gate valves control the flow. If the water is less than 60°C, it is heated electrically to that temperature. If, for any reason, the solar system must be shut down, cold water can be directly brought into the electric heater by opening the normally closed gate valve. If the water coming out of the auxiliary heater is too hot (greater than 60°C), cold water is mixed in to lower the temperature.

2. System Operation

The system has a number of operating modes. The system will turn "on" (the system will be receiving energy from the solar collectors) when the temperature of the collectors is greater than 27°C and the temperature of the water in the solar tank is less than 90°C. The system will turn "off" (the system won't be receiving energy from the solar collectors) when the temperature of the collectors drops to 23°C or the temperature in the solar water tank rises to 93°C. When the solar system is operating, the controller will position valve number one with "A" and "B" open and "C" closed. When the solar system is off, the controller will position valve number one with "B" and "C" open and "A" closed. Both pumps are operating at all times, whether the solar system is "on" or "off".

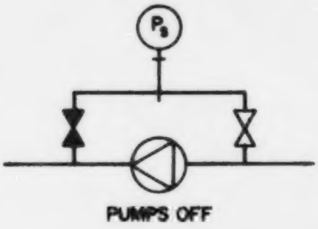
When the system is "on", the energy may be used to heat just the water, or to heat both the water and the air. If the temperature of the air is less than 16°C, the solar energy will be used to heat the air as well as the water. When the temperature of the air rises to 20°C, the valve will be moved so that only the DHW will be heated by the solar energy. If only the water is being heated, "A" and "B" will be open and "C" will be closed in valve number two. If both water and air are being heated, "A", "B" and "C" will be open.

When the system is "off", the energy stored in the solar tank will be used to heat the air if required. This mode will be activated if the temperature of the water inside the solar tank is greater than 38°C and the temperature of the air is less than 16°C. When the temperature of the water drops to 35°C or the temperature of the air rises to 20°C, this mode will be turned off. If this mode is operating, "B" is closed in valve number two and "A" and "C" are open. If this mode is not operating, "C" is closed and "A" and "B" are open (valve number two).

In order to follow the operational monitoring schedule, the following measurements must be understood:

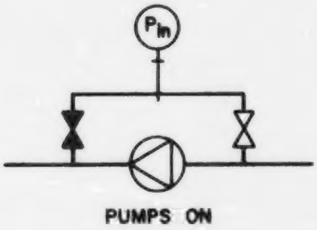
- number of cycles: During the course of a day, the solar system is turned on (pumps on) by the control system when sufficient solar energy is available. When the amount of energy drops to the point where operating the system is no longer practical, the controller turns off (pumps off) the solar system. Every time the controller turns the system on or off, an "event" is counted on the "event counter". It is important that the controller turns the pumps on and off at the appropriate conditions and, therefore, does not cause the system to cycle excessively. To verify that the controller is working properly, the "number of events" for a period are checked.

- system static pressure:



The static pressure is the pressure of the liquid in the piping system with the pumps off. The static pressure will be measured in both the primary loop (glycol) and the secondary loop (water). The procedure is the same for both cases. With the pumps off and the gate valve just down stream from the pressure gauge closed, the pressure gauge measures the static pressure.

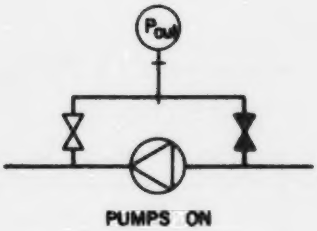
- inlet pump pressure:



The inlet pressure is the pressure of the liquid in the piping system just upstream of the pump when it is operating.

The inlet pressure will be measured in both the primary glycol loop and the secondary water loop. The procedure is the same for both cases. With the pumps on and the gate valve just downstream from the pressure gauge closed, measure the inlet pressure.

- outlet pump pressure:



The outlet pressure is the pressure of the liquid in the piping system just downstream of the pump when it is operating.

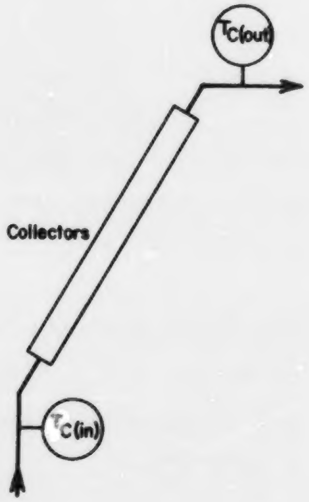
The outlet pressure will be measured in both the primary glycol loop and the secondary water loop. The procedure is the same for both cases. With the pumps on and the gate valve just upstream from the pressure gauge closed, the pressure gauge measures the outlet pressure.

- pump run time:

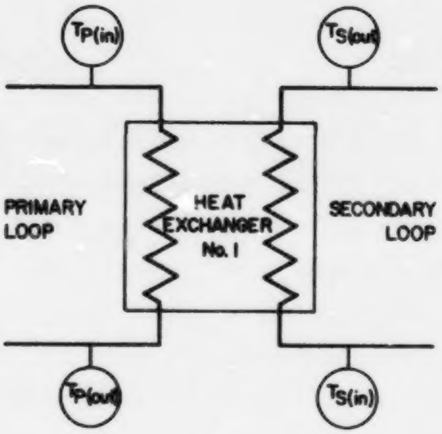
The run time meter attached to each pump clocks the time the pump is operating. This information is used to ensure that the system is operating close to the expected amount of time. Note: The run time meters cannot be reset so the additional hours over a period must be calculated.

- temperatures:

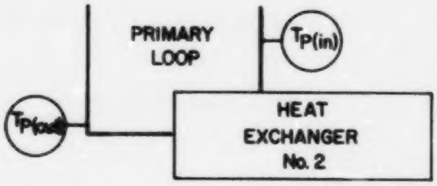
There are several permanently installed temperature probes with a digital readout:



- temperature of glycol/water mixture after it has been heated by the collectors, $T_{C(out)}$,
- temperature of glycol/water mixture before it has been heated by the collectors, $T_{C(in)}$,
- temperature of the glycol/water mixture before entering heat exchanger no. 1, $T_{P(in)}$,
- temperature of the glycol/water mixture after leaving the heat exchanger no. 1, $T_{P(out)}$,



- temperature of water in the secondary loop before entering heat exchanger no. 1, $T_{S(in)}$,
- temperature of water in the secondary loop after leaving heat exchanger no. 1, $T_{S(out)}$,



- temperature of glycol/water mixture before entering the secondary heat exchanger, heat exchanger no. 2, $T_{P(in)}$,
- temperature of the glycol/water mixture after leaving the secondary heat exchanger $T_{P(out)}$.

- system alarms:

The high limit thermostat sets off an alarm if the temperature of the fluid leaving the collector is greater than 95°C.

3. Introduction to Operational Monitoring

The prime purpose of operational monitoring is to detect a decrease in the solar system performance. This is done by regularly comparing certain indicators, such as temperatures, pressures and pump run times with those specified in the design and commissioning process. A change in these indicators to outside the design range means that the system has an operational problem. Identifying operational problems or system breakdowns as soon as possible is important in reducing damage to the system, and will also maximize the energy output of the solar system. Early detection of problems will also increase the life of the system, and keep operating and maintenance costs to a minimum.

Checks of instrument readings and verifications of the operation or condition of component equipment are conducted on a set of schedules as follows:

- daily,
- monthly, and
- semi-annually or yearly.

4. Operational Monitoring Procedures

Daily Operational Checklist

To ensure that no major malfunction of the solar system has occurred, the following questions should be considered daily. If the answer to any of the questions is "no", a problem has been detected. To determine the cause of the problem and the required action, see the Operator's Troubleshooting Guide.

Pumps

1. If the weather is sunny, or partially sunny, are the pumps operating?
2. If there is no sun, are the pumps off?

3. If the pumps are operating, is the period of operation reasonable? A problem is indicated if the event counter indicates more than ____ cycles per day. (In one cycle, the system turns on and then off, therefore, 10 cycles per day equals 20 events per day).

System Pressures

4. Is the system static pressure (P_S) within the acceptable range?
(acceptable range: primary loop 100 kPa to 120 kPa
secondary loop 280 kPa to 400 kPa)

5. If the pumps are operating, is the change in pressure across each pump in the specified range? (low, high)
(specified range (P_{out}-P_{in}):
primary loop 100 kPa to 110 kPa
secondary loop 30 kPa to 33 kPa)

6. If the pumps are operating, is the discharge pressure (P_{out}) relatively constant for each pump? (maximum deviation = 10 kPa)

System Temperatures

7. If the pumps are operating, is the rise in temperature between "storage to collector" and "collector to storage" within the specified range?
(acceptable rise in temperature:
2 °C to 10 °C for DHW heat exchanger
1 °C to 10 °C for ventilation unit heat exchanger)

General Overview

8. Does the status of all system alarms indicate normal system operation?
9. Have the pressure relief valves remained closed?
10. Are the vibration and noise levels normal?
11. Is the temperature of all mechanical equipment normal? (no overheating)

Monthly Operational Schedule

Every month a more detailed version of the "daily checks" will be performed and recorded in the chart shown on the following page. This procedure will provide an historical record of the solar system's performance as well as a closer examination of the system to check for possible problems. The monthly checks should be done on a day when solar energy is available and the system is cycling. Use the following procedure to obtain the values for the chart.

(a) Fill in general information; name, date, time, weather description and outside temperature.

(b) For each pump module:

Read and record the pump run time. Subtract the previous month's reading to find the monthly pump run time. Compare this with the expected value for the month. Being high or low may be a result of abnormal weather, but may also be an indication of problems.

Read and record the system static pressure (P_S), the pump discharge pressure (P_{out}), and the pump suction pressure (P_{in}).

Calculate and record the pressure difference across the pump ($P_{out} - P_{in}$).

(c) Read and record the following temperatures:

for Heat Exchanger No. 1:

- Primary circuit heat exchanger: in $T_{P(in)}$
- Primary circuit heat exchanger: out $T_{P(out)}$
- Secondary circuit heat exchanger: in $T_{S(in)}$
- Secondary circuit heat exchanger: out $T_{S(out)}$
- Solar storage tank: top, bottom

Calculate ($T_{P(in)} - T_{P(out)}$) and ($T_{S(out)} - T_{S(in)}$). Record.

MONTHLY OPERATIONAL RECORD

GRAYSTONES PUBLIC SCHOOL

OPERATOR	MONTH	DAY	TIME	WEATHER		PUMP MODULE NO.1							PUMP MODULE NO.2							TEMPERATURES (°C)								TEMPERATURES (°C)								Control Module		Drain Down System	
				CLEAR, VARIABLE, or OVERCAST	OUTDOOR TEMP (°C)	Run Time (hrs)			Pressure (kPa)				Run Time (hrs)			Pressure (kPa)				Heat Exchanger No. 1						Solar Storage Tank		Heat Exchanger No. 2						Solar Storage Tank		EVENTS TO DATE	EVENTS FOR MONTH	TIME TO DRAIN (min)	LEVEL (from top)
						TOTAL	MONTHLY	EXPECTED	P_S	P_{out}	P_{in}	$P_{out} - P_{in}$	TOTAL	MONTHLY	EXPECTED	P_S	P_{out}	P_{in}	$P_{out} - P_{in}$	PRIMARY		SECONDARY		$T_{P(in)} - T_{P(out)}$	$T_{S(out)} - T_{S(in)}$	TOP	BOTTOM	PRIMARY		SECONDARY		$T_{P(in)} - T_{P(out)}$	$T_{S(out)} - T_{S(in)}$	TOP	BOTTOM				
																				In $T_{P(in)}$	Out $T_{P(out)}$	In S(in)	Out $T_{S(out)}$					In $T_{P(in)}$	Out $T_{P(out)}$	In $T_{S(in)}$	Out $T_{S(out)}$								
									100 120			100 110				280 400			90 33					2 10								1 10					300		
	Jan.							90							90																								
	Feb.							120							120																								
	Mar.							120							120																								
	Apr.							180							180																								
	May							240							240																								
	June							240							240																								
	July							210							210																								
	Aug.							210							180																								
	Sept.							180							180																								
	Oct.							150							150																								
	Nov.							120							120																								
	Dec.							90							90																								

SYSTEM FAILURE REPORT

OPERATOR	DATE	DESCRIPTION

for Heat Exchanger No. 2:

- Primary circuit heat exchanger: in $T_{P(in)}$
- Primary circuit collector: feed $T_{P(out)}$

Calculate $(T_{P(in)} - T_{P(out)})$.
Record.

(d) For each control system module, read and record the number of events to date. Calculate the number of events for the month and compare it to the acceptable range.

(e) Analysis of monthly record:

Compare all readings and calculated values to their specified ranges. If they are outside of the range, consult the Operator's Troubleshooting Guide.

(f) The following preventative maintenance checks should also be performed:

- clean collector glazing where necessary,
- inspect collectors for the following:
  - weep holes full of debris, insects, ice, etc.,
  - deterioration of the absorber plate in the form of discolouration or buckling,
  - permanent condensation on the underside of the collector glazing,
  - temperature variance: a collector that is noticeably cooler or warmer than the others indicates a flow blockage or imbalance (a heat meter reading of the collector surface temperature will do),
- check mounting hardware security and caulking as well as flashing around roof penetrations,
- lubricate pumps, motors and control linkages as required.

Semi-Annual Operational Maintenance Schedule

Semi-annual checks will be conducted each spring and fall. The schedule includes several repeats of test procedures that were done as part of the start-up and commissioning, along with preventative maintenance checks.

Fluid Quality

Three characteristics of the glycol need to be checked semi-annually. If the facilities are not available "in-house", send a 50 ml sample of glycol to an analysis lab.

1. Determine the percentage of glycol to water using a hydrometer, refractometer, or by the ASTM E 203 - 75 - Water using Karl Fischer Reagent. The percentage of glycol determines the freeze point of the solution. The percentage of glycol must be greater than 45 % and less than 55 %. If it is out of the acceptable range, alter it.

2. Determine the pH factor (a measure of the acidity of the solution) in accordance with the ASTM D 1613 - 66 (Reapproved 1972). In order to minimize corrosion, the pH of the solution must be greater than 7 and less than 9 .

3. Determine the reserve alkalinity (a measure of the amount of inhibitor available to react with and neutralize acids formed in the glycol) in accordance with ASTM D 1121-72 Reserve Alkalinity of Engine Antifreeze, Antirusts and Coolants. If the reserve alkalinity is not within the range 10 to 12 , restore it to the required level by using the manufacturer's method.

Heat Exchanger Effectiveness (Heat Exchange No. 1)

The test should be carried out using the design hot water draw on the load side.

The design hot water draw rate is _80_ L/min.

With the pumps operating, measure and record the following temperatures;

$T_{P(in)}$ - primary side inlet ______°C

$T_{P(out)}$ - primary side outlet ______°C

$T_{S(in)}$ - secondary side inlet ______°C

$T_{S(out)}$ - secondary side outlet ______°C

Calculate the heat exchanger effectiveness (E) using the following equation: (Note: counter flow heat exchanger, minimum heat capacity rate on the secondary side)

$$E = \frac{T_{S(out)} - T_{S(in)}}{T_{P(in)} - T_{S(in)}}$$

Heat exchanger effectiveness __________

A problem is indicated if the effectiveness is not within the following range: _.7_, _.75_.

Sensor Calibration Check

Sensor accuracy can change with time due to the build up of corrosion at the attachment points or the lead connections. Sensor accuracy can also be distorted when it experiences temperature extremes that exceed its design range. Since combined inaccuracies in both the collector and storage sensor inputs can significantly reduce the system performance, sensor calibration checks should be performed semi-annually.

A total of four tests are required:

1. collector sensor at cool temperature (early in morning on cloudy day),
2. collector sensor at hot temperature (mid to late afternoon on sunny day),
3. storage tank sensor at cool temperature,
4. storage tank sensor at hot temperature.

For each test, measure the temperature at the point and the resistance at the control connection. Compare the readings to the temperature-resistance curve supplied by the manufacturer. If there is a discrepancy, corrosion or extreme temperatures could have damaged the sensor or its connections. Check both and replace, if necessary, then repeat the test.

Preventative Maintenance

- Clean filters and strainers
- Cycle or operate valves to assure functioning
- Oil or lubricate components according to the manufacturer's recommendations
- Check charge on expansion tank

TROUBLESHOOTING GUIDE

GRAYSTONES PUBLIC SCHOOL
CLOSED LOOP SOLAR SYSTEM - SPACE AND WATER HEATING

TROUBLESHOOTING GUIDE

Symptom	Source	Cause	Action
No hot water or heat	Make-up water shut-off valve	Valve closed	Open valve.
	Auxiliary heater	Failed to activate	Check breaker or fuse. Check power to heater. Check fuel supply.
Hot water temperature too low	Hot water thermostat	Thermostat setting too low	Set thermostat higher.
	Auxiliary heater	Not functioning	Check breaker or fuse. Check and repair auxiliary heating unit and fuel supply.
	Temperature modulating valve	Faulty	Repair or replace.
		Temperature set too low	Reset.
Water temperature too high	Hot water thermostat	Thermostat setting too high	Reset.
		Thermostat out of calibration	Recalibrate.
	Temperature modulating valve	Faulty	Repair or replace.
		Temperature set too high	Reset.
Insufficient hot water to load, but solar system seems normal	Auxiliary heater	Auxiliary heater problems	Check auxiliary heater, wiring, gas, oil lines, burners, and set points.
	Valves	Isolation valves improperly closed	Set in proper positions.
	Temperature modulating valve	Improperly adjusted	Check adjustment. Adjust as necessary.
		Faulty	Repair or replace.

Symptom	Source	Cause	Action
Insufficient heat but solar system seems normal	Auxiliary heater	Auxiliary heater problems	Check auxiliary heater, wiring, gas, oil lines, burners, and set points.
	Valves	Isolation valves improperly closed	Set in proper positions.
Drop in water pressure at both hot and cold outlets	Inlet water pressure	Inlet strainer clogged	Clean basket.
	Pressure reducing valve	Malfunctioning	Check for plugged ports, and proper operation. Clean, repair, or replace.
Drop in water pressure at hot outlets only	Valves	Valve improperly closed	Open manual valves Check automatic valve operation, repair or replace.
		Jammed check valve	Repair and replace.
	Strainers	Flow restriction	Check and clean.
System does not start or Pump(s) not running when solar energy available	Power supply	Control switch in "off" position	Turn to "auto" position.
		No power to pump	Check fuses or circuit breaker. Check wiring and connections.
		No power to controller	Check fuses or circuit breaker. Check wiring and connections.
	Pump	Pump seized	Try turning by hand. Repair or replace.
		Motor failure	Repair or replace.
	Controls	Control failure	Try on "manual". If pump runs suspect control system. (Refer to Troubleshooting Controls)
		Pressure cut offs activated	Rectify cause, reset.
		Temperature cut off activated	If tank temperature below high limit cut off, check control system. (Refer to Troubleshooting Controls)

Symptom	Source	Cause	Action
		Fault in control system	Check control system. (Refer to Troubleshooting Controls)
		Electrical problem	Check line terminal voltage.
Pump(s) running when no solar energy available	Control system	Control set on "manual"	Set on "automatic".
		Fault in control system	Check control system. (Refer to Troubleshooting Controls)
Pump cycling excessively	Controls	Incorrect set points	Check set point.
		Fault in control system	Check control system. (Refer to Troubleshooting Controls)
System static pressure low	Charge pressure low	Fluid level low	See "Fluid level low".
	Expansion tank (Diaphram)	Bladder capacity exceeded or diaphram leaking	Inspect for fluid in air chamber, replace expansion tank.
	Expansion tank (Standard)	Inadequate air space	Adjust liquid level.
		Air leak	Find and correct.
Fluid level low	Leak in system	Piping leak	Repair. Replace wet insulation.
		Leak from drain	Close drain tightly, add cap.
		Leak from air vent	Inspect, clean mechanism, repair or replace.
	Pressure relief valve	Relief valve has expelled excess pressure	Find cause for excess pressure; correct. Recharge system to operating pressure.

Symptom	Source	Cause	Action
System static pressure high	Controls	Overtemperature	Find cause. (Refer to Troubleshooting Controls)
	Fluid	System overfilled	Check level.
	Expansion tank	Expansion tank is waterlogged	Check expansion tank liquid level. Check for air leak.
Pump discharge pressure fluctuating	Pump	Cavitation	Find source of air entry, check for restriction on suction side, clean strainer.
Storage temperature decays during periods of no load	Insulation	Damaged or wet	Repair or replace.
	Check valve	Reverse thermosyphoning	Inspect check valve operation. Repair or replace.
Storage temp remains high during high load, little solar	Valves	Isolation valves improperly closed	Set in proper position.
Poor solar energy collection	Collector array	Film on collector glazing	Check for dirt on glazing. Check for condensation and outgassing. Clean glazing.
		New source of shading	Check for new structures growth of trees, etc.
		Flow rate	Check flow rate. Reset to specified flow.
			Check operation of automatic flow control valve. Repair or replace as necessary.
		Flow balance	Check balance of flow through collector banks. Rebalance as necessary.
			Check operation of automatic flow control valves. Repair or replace as necessary.
		Scale forming in collector tubes	Flush collector loop.

Symptom	Source	Cause	Action
	Piping	Insufficient or damaged insulation	Check condition and adequacy of insulation. Repair, replace or add additional insulation.
	Collector fluid	Antifreeze/water concentration in collector loop fluid is improper	Check fluid properties. Follow manufacturer's recommendations.
		Reverse thermosyphoning	Inspect check valve operation. Repair or replace.
	Controls	Out of calibration	(See "Troubleshooting Controls")
Excessive vibration or noise in system	Pump	Cavitation	Check for air entry, check for resriction on pump suction side, clean strainer.
		Bearings	Check for hot or worn bearings. Check bearing alignment.
		Impeller	Inspect for misaligned shaft, repair, replace. Check balance of impeller. Clean, repair or replace.
	Piping	Entrapped air	Check automatic air vents. Vent manually. Force purge system, find and correct source of air entry.
		Supports	Check condition and adequacy of hangers. Repair hangers or install additional hangers.
Water hammer	Automatic valves	Open or close too fast	Install valves with slower action. Modify controls to slow valve action.

The following section of the diagnostic chart will be helpful if either the pump operating pressures or the system ΔT as defined in the operator's manual are out of the specified range

Pump discharge pressure not design range	If this condition is found carry out the following checks:

1 Check system static pressure and insure that it is in the proper range.

2 Using the pump inlet pressure and the pump discharge pressure, determine the pressure difference across the pump (ΔP).

Symptom	**Source**	**Cause**	**Action**
ΔP high		Generally the result of a flow restriction of some type	
	Valves	Flow control valves tampered with (closed)	Check seal on valves, if tampered with adjust flow as per commissioning procedure.
		Shut-off valves closed	Open.
		Automatic valves closed	Check controls, operation, and springs, repair or replace.
	Check valve	Jammed	Repair or replace.
	Air vents	Faulty -- causing air lock	Operate needle valve manually; check float control, inspect, clean, repair or replace.
	Collector	Passages clogged	Feel if some collectors hotter than others. Remove collector, backflush passages.
	Strainer	Flow restriction	Check and clean strainers.
ΔP Low	Valves	Flow control valves tampered with (closed)	Check seal on valves, if tampered with, adjust flow as per commissioning procedure.
	Three-way valves	Internal leaking	Check and repair.

Symptom	Source	Cause	Action
	Pump	Cavitating	Find source of air entry. Check for flow resriction on suction side, clean strainer.
		Mechanical failure	Check and repair.
ΔT low ΔP(s) normal	Collectors	Dirty	Clean surface.
		Insulation wet	Dry or replace insulation., Reseal collectors.
		Excessive condensation	Inspect seal, pipe gaskets, and weep holes. Repair.
	Pipe or tank insulation	Damaged, wet or missing	Repair or replace.
	Heat exchanger	Scaled up	Clean heat exchanger.
	Controls	Setting incorrect or drifting	Reset. (See "Troubleshooting Controls")
ΔT low ΔP(s) low	Flow control valves	Tampered with (opened)	Check seals on valves. If tampered with, adjust flow as per commissioning procedure.
	Three-way valves	Internal leaking	Repair.
	Controls	Incorrectly set	(See "Troubleshooting Controls")
ΔT high ΔP(s) normal	Controls	Incorrectly set	(See "Troubleshooting Controls")
ΔT high ΔP(s) low	Pump	Cavitation	Find source of air entry, correct, clean strainer, check for restriction on suction side.
		Impeller damage	Check stagnation pressure. Repair.
	Three-way valves	Internal leak	Check and repair.

Symptom	Source	Cause	Action
ΔT high ΔP high		Generally the result of a flow restriction of some type	
	Valves	Flow control valves tampered with (closed)	Check seal on valves. If tampered with adjust flow as per commissioning procedure.
		Shut-off valves closed	Open.
		Automatic valves closed	Check controls, operation, and springs. Repair or replace.
	Check valve	Jammed	Repair or replace.
	Air vents	Faulty - causing air lock	Operate needle valve manually; check float control, inspect, clean, repair or replace.
	Collector	Passages clogged	Feel if some collectors hotter than others. Remove collector, backflush passages.
	Strainer	Flow restriction	Check and clean strainers.
Pump run time too high			(See "Pump(s) running when no solar energy available")
Pump run time too low			Check T and P(s) and refer to appropriate section, if cause not evident, refer to "System Diagnostic Procedures".

TROUBLESHOOTING SOLAR CONTROLS

In troubleshooting solar controls, it is important to use a logical and systematic approach in isolating and correcting system faults. The following is the recommended procedure. This procedure is for variable resistance type controllers. For I.C. controllers, which use variable voltage sensors, voltages are measured instead of resistances.

Differential Controller Checks

1. Check power supply to controller.

2. Check that all components are wired correctly to controller (according to manufacturer's specifications).

3. If the pump or valve does not work in the "manual" mode, disconnect it from the controller and apply rated voltage to its input wires at the controller.

   a. If it runs, the pump is all right - the problem is in the control system.

   b. No operation - the pump or valve is faulty or the interconnecting wiring or relay is faulty. Isolate the fault and repair or replace the defective component.

4. Check all sensors for:

   - proper location,
   - secure attachment with no corrosion build-up,
   - proper wiring to controller.

5. Check each sensor for proper resistance by disconnecting it at the controller. If the measured resistances are as specified,

the fault is a controller problem. Proceed to Step 8. If the measured resistances do not correspond to the specification value for the temperature of the sensor location, then:

- the sensor is faulty,
- the interconnecting wiring is faulty.

6. Disconnect sensor from wiring leading to the controller. Check the sensors resistance at this point. If the resistance is not to specification, replace the sensor.

7. If sensor is accurate, check for corrosion at all wiring connections. Clean, reconnect and remeasure resistance at the controller. If the measured resistance is still not correct, replace the wiring between the sensor and the controller.

8. Controller operational check.

   - switch off the electrical power to all pumps and/or control valves and make sure the controller is set for the recommended temperature differential;

   - replace the temperature sensors at the collector and the tank with variable resistors (variable resistors with readouts will simplify the procedure). The resistors can be connected to the sensor terminals at the controller;

   - from the temperature sensor characteristic curve, determine the resistance associated with 5°C absolute temperature;

   - dial this resistance into the variable resistor on the output to the tank sensor. Record the resistance;

- with the controller set in the automatic position, gradually change the resistance on the collector side until an output is measured at the controller output terminals (to pump or control valve). Record the indicated resistance;

- vary the resistance until there is no longer an output at the controller output terminals. Record the indicated resistance;

- reset the tank variable resistor for the resistance associated with a 15°C absolute temperature;

- repeat the above procedure determining the collector resistance to receive an output at the output terminal and the resistance to receive no output. Record both resistances;

- calculate the differential resistance, and from the temperature sensor characteristic curve determine the temperature differential;

- compare this with the original setting of differential temperature;

- if the two figures disagree substantially (more than ten percent), adjust the controller setting and repeat the above test.

9. Sensor Calibration Check

Preparation

1. Obtain a copy of the temperature sensor characteristic curve from the appropriate manufacturer (resistance vs. temperature).
2. Obtain a digital multimeter with an appropriate probe to determine as accurately as possible the temperature at the point the sensor is intended to sense.

Method

Determine the temperatures at the points the sensor is intended to sense. These will likely be the absorber plate in one of the collectors and the temperature in the lower third of the storage tank.

Measure with an ohm meter the resistance shown by the sensor. This should be done at two temperatures for each sensor, for example:

For collector sensors:

1. Cool Temperature - as early as possible in the morning, preferably on a cloudy day.

2. Hot Temperature - mid to late afternoon on a sunny day.

For storage tank sensors:

1. Cool Temperature - after a major draw of heat from storage to load on a cloudy day and before the auxiliary heat has replenished the draw (where applicable).

2. Hot Temperature - late on a sunny day before a major draw of heat or on a day when the load is reduced.

Compare the measured resistance with that shown on the manufacturer's table or graph for the appropriate temperature.

If the resistance varies from the expected value, the sensor or sensor lead connections may be corroded or the sensor may have been damaged by heat extremes. Check both and replace as necessary then repeat the test.

Freeze Protection Controls

Thermal switch sensors are used for freeze protection of the collector loop on drainback systems or the heat exchanger on closed loop systems.

The freeze protection set point should be at least 3°C (5°F) above the actual freezing point. Once the thermal switch set point is reached, the switch should de-activate the pump on drain back systems, causing the system to drain. In closed loop glycol systems, the freeze protection thermal switch circuit prevents the pump running in the event of a controller failure.

Sensors used for freeze protection may be either the thermal switch type or variable resistance type.

Test Procedure for Thermal Switch Type

1. Connect the thermal switch to an ohm meter so you can see when it changes state. Seal the sensor along with a thermometer in a plastic bag. Place the bag into cool water and add ice for further cooling. When the sensor changes state, record the temperature and ohm meter reading. Slowly warm the water and sensor until it changes state again. Record the temperature and ohm meter reading. The first set of readings is the low temperature limit set point and the second is the temperature at which heat collection can restart.

2. After checking the thermal switch, connect it to the controller or pump circuit and retest by varying the temperature as described, and verify that the proper response occurs.

Test Procedure for Variable Resistance Types

1. If freeze protection circuit uses a thermistor, nickel wire or film as its sensor, then a variable resistor whose resistance range passes through that of the low temperature set point should be connected to the collector sensor inputs. A resistor with a value somewhat less than the collector freeze point should be connected to the storage

input. With the appropriate load connected to the controller, connect the controller to the power input. The variable resistor should be varied above and below the freeze protection set point. Verify that the appropriate response occurs at the temperatures and resistance values specified by the manufacturer.

High Temperature Limit Protection

High temperature limit switches are used in solar systems either to protect collectors, storage tanks or as a secondary safeguard against failure of the mixing valve on the outlet to load.

Control logic should be set up so that the temperature limit switch will not inhibit the initial start up of the collector loop pump, but will activate if, after a reasonable length of time, the collector temperature has not fallen.

For closed loop glycol systems, the high temperature limit or control logic may be used to divert flow to a heat purge coil.

High Temperature Protection for Storage Tanks

High temperature limit switches are used to protect storage tanks from over temperature conditions. In some cases, a tank temperature limit can serve as a secondary protection against scalding temperatures being delivered to load if the mixing valve fails.

High Temperature Limit Switch Checkout

The checkout procedure is similar to that for freeze protection. The switch or sensor is immersed in hot water, which is heated until the device activates and then cooled until it reverses. The temperatures and resistances for these points are recorded and checked against the specifications.

GENERAL SYSTEM DIAGNOSTIC PROCEDURE

The performance of a solar system depends on the interaction of all system components, outside conditions, and the load imposed on the system.

There are cases in which a general decrease in the performance of a system is indicated by a decrease in system operating time, temperature differences, measured energy collected, or by an increase in the required auxiliary energy. In some cases, the particular problem cannot be isolated by the operator. The following is a general diagnostic procedure which can, in most cases, isolate the causes.

Carrying out this procedure requires some knowledge of solar systems and a number of portable instruments; therefore, a troubleshooting technician or engineer may be required.

1. The first step is a visual inspection of the system paying special attention to such items as completeness and condition of insulation and whether the collectors are clean and free of new shading.

2. Verifying flow rates.

   The operating flow rates in each loop should be checked by the means provided. This may be by using pump differential pressures or by reading a flow meter if one is installed in the particular loop. (See commissioning procedure.)

3. If the flow rate in any loop in the system is lower than specified, the flow restriction can be isolated by checking the pressures at the monitoring points provided in the system and comparing these with the commissioned values.

4. If the flow rates in all points of all loops are as specified, check the fluid temperatures at each monitoring point on a clear sunny day.

5. Verify the flow balance through the collector banks.

   The face temperature of each collector should be checked by feel or, preferably, with a pyrometer. Collectors that are significantly warmer or cooler than their neighbours indicates flow blockages and stagnation or high flows respectively.

   It is a good idea to check the bank temperature balance by the method shown in the commissioning procedure.

6. Verify the effectiveness of the heat exchanger as in the commissioning procedure. A reduced effectiveness could indicate scaling of the heat exchanger surfaces.

7. Perform the preliminary thermal performance test as shown in the commissioning procedure and compare the efficiency with the commissioned values. This will detect degradation of the collectors' performance.

8. Check the calibration of the control system as described in "Troubleshooting Solar Controls."

If satisfied that the operating characteristics of the system are normal, investigate the non-operating features.

9. Isolate the system from load and bring the storage temperatures up during the day. Read the storage temperature at nightfall and shut off the system. Check the storage temperature in the morning. If the storage temperature has dropped significantly, suspect damaged or wet insulation, or reverse thermosyphoning (usually the result of a faulty check valve).

PERFORMANCE MONITORING

GRAYSTONES PUBLIC SCHOOL
CLOSED LOOP SOLAR SYSTEM - SPACE AND WATER HEATING

One meter is required to determine the overall performance of the solar heating system.

The selected meter is a:

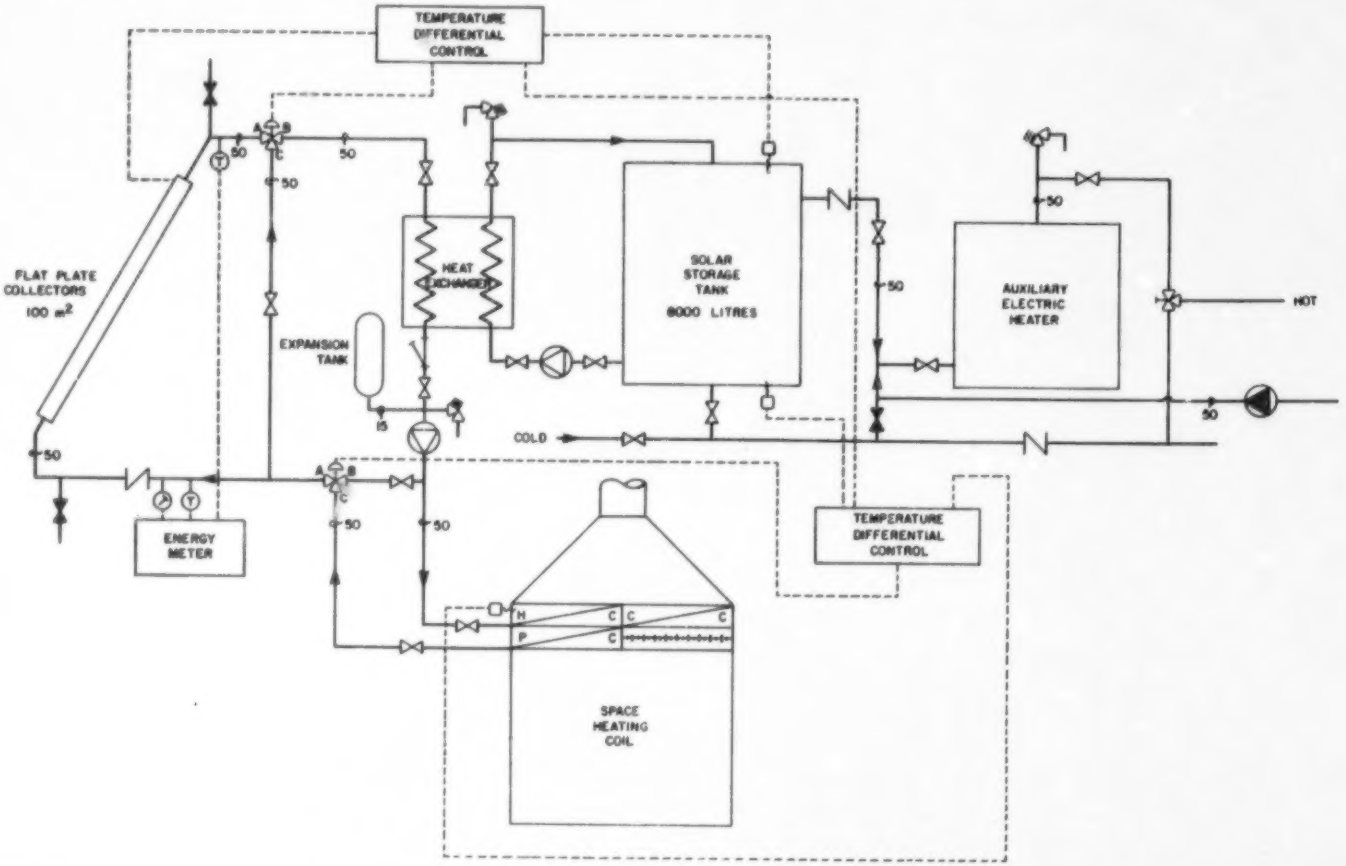
ISTA Model 50 Energy Meter
- readout in kilowatt-hours
- supplied with a 2 inch flow meter

available from:

Con-Serve Group
18 Gradwell Drive
Scarborough, Ontario
(416) 266-9635

Note the figure illustrating the arrangement of the performance monitoring equipment.

A sample form, on which this performance data will be recorded each month, is also attached.



LEGEND

Ⓣ TEMPERATURE PROBE

⊘ FLOW METER

DATE	MAY, 1982
DESIGNED	S B
DRAWN	C H
CHECKED	J R

ACME ASSOCIATES
Engineers/Ingénieurs

GRAYSTONES PUBLIC SCHOOL

Closed Loop Solar
Space and Water Heating System

Schematic with
Performance Monitoring Equipment

SCALE	PROJECT NO	DWG. NO	REV
N T S	1425 - 81	5	

"SYSTEM C"

MONITORING MONTHLY REPORT

PROJECT NAME: Graystones Public School

PROJECT NUMBER: 345678901

DATE:

Please fill in energy quantities indicated below:

SOLAR ENERGY INPUT (meter number)

RECORD OF SYSTEM PROBLEMS:
(Briefly explain any system problems encountered)